UNIVERSITY OF BRISTOL

THE ANNUAL REPORT

OF THE

Agricultural and Horticultural Research Station

(THE NATIONAL FRUIT AND CIDER INSTITUTE)

LONG ASHTON, BRISTOL

1947

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A. ESMOND ROBINSON, Esq., O.B.E., M.C., The Batch, Flax Bourton, near Bristol.

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Secretary.

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(WINIFRED SHAPLAND, M.A.).

STAFF, 1947.

Director :
PROFESSOR T. WALLACE, C.B.E., M.C., D.Sc. (Dunelm), F.R.I.C.

Chemistry : Soils & Plant Nutrition :	T. WALLACE, C.B.E., M.C., D.Sc. (Dunelm), F.R.I.C.
	C. BOULD, M.Sc., Ph.D. (Reading).
	D. J. D. NICHOLAS, B.Sc. (Hons.) (Lond.), Ph.D. (Bristol), A.K.C., Agricultural Research Council Plant Nutrition Scheme.
	J. A. H. TOLHURST, B.Sc. (Agric. Chem.) (Hons.) (Reading), transferred from Agricultural Research Council Hop Diseases Investigations to Soil Chemistry, 1/3/47.
	C. F. MILLS, B.Sc. (Hons.) (Agric. Chem.) (Reading), Agricultural Research Council Plant Nutrition Scheme. *Resigned* 31/7/47.
Chemistry : Insecticides & Fungicides :	H. MARTIN, D.Sc. (Lond.), A.R.C.S., F.R.I.C.
Bio-Chemistry :	A. POLLARD, M.Sc. (Lond.), Ph.D. (Manchester).
	Miss M. E. KIESER, B.Sc. (Hons.) (Bristol), A.R.I.C.
	Miss J. D. BRYAN, B.Sc. (Hons.) (Bristol). *Resigned* 30/11/47.
Organic Chemistry .	D. WOODCOCK, M.Sc., Ph.D. (Dunelm), A.R.I.C.
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Physical Chemistry :	W. D. E. THOMAS, B.Sc. (Hons.), Ph.D. (Wales), A.R.I.C.
Entomology :	H. G. H. KEARNS, B.Sc. (Lond.), Ph.D. (Cantab.), Dip. Agric.
	S. H. BENNETT, B.Sc. (Hons.) (Bristol).
	N. G. MORGAN, B.Sc. (Hons.) (Bristol).
	A. STRINGER, B.Sc. (Hons.), A.R.C.S. (Lond.), Agricultural Research Council Insecticidal Bio-Assay Scheme.
Mycology :	R. W. MARSH, M.A. (Cantab.).
	S. H. CROWDY, B.Sc. (Hons.), A.R.C.S. (Lond.).
Plant Physiology :	E. J. HEWITT, B.Sc. (Hons.) (Lond.), Ph.D. (Bristol), A.K.C.
	W. PLANT, B.Sc. (Hort.), Ph.D. (Reading), N.D.H., Agricultural Research Council Plant Nutrition Scheme.
	E. W. JONES, M.Sc. (Wales), Agricultural Research Council Plant Nutrition Scheme.
Pomology :	G. T. SPINKS, M.A., Dip. Agric. (Cantab.).
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	E. W. HOBBIS, B.Sc. (Bristol), N.D.H., Plantations Officer.
	W. R. STANTON, B.Sc. (Hort.), (Reading), Cider Orcharding.
Cider :	B. T. P. BARKER, M.A. (Cantab.) (Part-time).
	S. W. CHALLINOR, B.Sc. (Hons.), Ph.D. (Birm.), D.Sc. (Edin.), F.R.I.C.
	L. F. BURROUGHS, B.Sc. (Hons.) (Reading), A.R.I.C.
Fruit & Vegetable Preservation :	Miss B. A. CRANG, B.Sc. (Lond.).
	Mrs. D. P. JAMES, B.Sc. (Bristol).
	Miss M. STURDY, B.Sc. (H. & S.S.) (Lond.), Instructress.

ASSISTANT STAFF.

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Pomology :	S. H. LEGGE, Marketing Officer and Recorder.
	E. G. CLOTHIER, Station Guide and Meteorological Recorder.
	E. UMPLEBY, Propagator and Recorder.
	E. CATLOW, Recorder.
	H. LOCKE, Horticultural Assistant.
	W. H. NEILD, Horticultural Assistant. *Resigned* 31/7/47.
Laboratories :	F. E. MALTBY, Chief Laboratory Steward and Research Assistant.
	A. H. WILKINS, Research Assistant (Entomology).
	G. H. JONES, Research Assistant (Chemistry and Photography).
	R. F. BATT, Research Assistant (Chemistry : Insecticides and Fungicides).
	W. J. REDMOND, Analyst. Agricultural Research Council Plant Nutrition Scheme. *Appointed* 8/12/47.
	Miss M. D. ATHERTON, Research Assistant (Fruit and Vegetable Preservation).
Plantations :	A. J. HURDLE, Plantations Foreman.
	R. M. JARRETT, Assistant Recorder.
	J. A. BERENDT, Assistant Recorder. *Resigned* 11/8/47.
	Miss M. PORTER, Dip. Hort. (Studley), Assistant Recorder (Willows). *Resigned* 31/10/47.
	Miss C. E. C. CLARKE, Assistant Recorder.
	Miss E. I. M. PRESCOTT, Assistant Recorder.
	Mrs. M. R. LEWIS, Assistant Recorder.
Cider :	R. J. HATHWAY, Cider Maker.
	J. H. LLEWELLYN, Technical Assistant.
Estate Work :	S. E. COLE.
Office :	Mrs. A. I. EDBROOKE, Cashier.
	Miss A. M. EVANS, Director's Secretary.
	R. A. MERCHANT, Chief Clerk, Accounts.
	D. H. PITTMAN, Senior Clerk.
	G. F. FOSTER, Ledger Clerk. *Resigned* 4/10/47.
	J. PACKER, Ledger Clerk. *Released from R. A. F.*, 18/8/47.
	Miss E. M. MATTHEWS, Clerical Assistant.
	Miss I. A. PEARCE, Clerical Assistant.
	Miss V. E. R. ALSOP, Clerical Assistant.
	Miss I. TRICKEY, Clerical Assistant.
	Miss J. FOSTER, Clerical Assistant, *Resigned* 8/11/47.
	Miss I. E. TAYLOR, Library Clerk, *Appointed* 23/6/47.
Secretary :	A. L. LEGGETT, A.S.A.A.

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INTRODUCTION.

By T. WALLACE, C.B.E., M.C., D.Sc., F.R.I.C.

In the 1946 report a number of changes and post-war developments were noted which were likely to affect the work of the Institute during 1947. Prominent among these was the establishment of the National Agricultural Advisory Service in October, 1946, which terminated all the advisory work of the Institute with the exception of that relating to Cider and Perry manufacture. It was found in the early months of the change-over that many farming and fruit-growing advisory enquiries continued to be addressed to the Institute but this position has been gradually corrected and by close co-operation with the Bracken Hill Advisory Centre such enquiries have been transferred to that centre and distributed to the appropriate advisory officers without undue delay.

During the year a number of requests were received from officers of the N.A.A.S. in various parts of the country for members of staff to give lectures to growers' associations and to contribute papers at organised conferences. In order to regularise procedure and to keep the requests within limits which would not interfere unduly with the work of members of staff, it was decided that all such engagements should be made through the N.A.A.S. Headquarters staff at the Ministry of Agriculture. The arrangement has worked well and the staff have welcomed the opportunity of helping their advisory colleagues in the initial stages of the new service.

As stated in the previous report the revised scheme of membership of the Institute, necessitated by the curtailment of the Station's advisory services, was approved by the Annual Meeting of Members of the National Fruit and Cider Institute in July, 1947, and came into operation on January 1st, 1948.

Another important event during 1946 was the reconstitution of the Cider Advisory Committee which quickly settled down, through its sub-committees, to grapple with some of the outstanding technical problems of the cider industry. Under its aegis a conference was held at the Institute on 27th February, 1947, to consider ways and means of increasing the supplies of cider fruit both to meet immediate demands and as a long term policy. The conference was attended by representatives of all the various interests involved in the production and utilisation of cider fruit—the National Association of Cider Makers, the Apple Juice Producers' Association of Great Britain, the National Farmers' Union, the Horticultural Trades' Association, contributing County Councils, the Bath and West and Southern Counties Society and the National Agricultural Advisory Service.

As the outcome of this conference, further local conferences were organised during the autumn at Hereford, Stoke Canon (Devon) and Bristol, at which the problems of cider fruit production were further discussed.

The Cider Orcharding and Supplies Sub-Committee of the Cider Advisory Committee also considered the question of suitable cider varieties for immediate post-war planting in the various cider-orcharding districts and eventually drew up lists of recommended varieties both for general and local planting which were agreed by the full committee and circulated to the official departments and organisations represented on the Committee and also made known to farmers through the medium of the recognised official and trade journals. The work of the Committee has done much to stimulate interest in cider orcharding and moreover has proved a valuable means of bringing together cider fruit

growers, cider makers and apple juice manufacturers. It seems likely that an important development will be the establishment of local committees of growers and cider makers, probably on a county basis, to discuss problems of mutual interest. A committee of this sort has already been convened in Herefordshire and it seems likely that another will shortly be formed in Devon.

During the year an important decision was made by the Government Departments concerned with regard to the future arrangements for work on Cider and Fruit Products. Hitherto research on Cider Making and Cider Orcharding had been carried out under the Agricultural Research Council and financed through the Ministry of Agriculture, whilst work on Fruit Products has been financed by grants made to the Agricultural Research Council by the Department of Scientific and Industrial Research. These arrangements were concluded on March 31st, 1947, from which date the following scheme came into force.

Research on Cider manufacture and Fruit Products became the joint responsibility of the Department of Scientific and Industrial Research, the Agricultural Research Council and the Ministry of Agriculture, the arrangement to be continued in the first instance for a period of five years. The work is to be directed and supervised by a committee to be set up by the Agricultural Research Council, the members of which are to consist of representatives of the three responsible government departments, various trade interests and the Long Ashton Institute.

This committee will approve the annual programmes of research and receive progress reports on the work. Cider orcharding research is not included in this scheme but remains on the old basis as the joint responsibility of the Agricultural Research Council and the Ministry of Agriculture.

In the other sections of the Institute steady progress has been made with research projects as will be evident from the later section of this report dealing with research activities. Lack of accommodation has, however, remained a serious handicap, due to the fact that it was not possible to complete the new Biological building in the autumn of 1947 as had been originally estimated. It is now expected that this building will be ready for occupation some time during the first half of 1948.

The special grant for Hop investigations was concluded on February 28th, 1947, and in future Hop research is to be centralised at a special centre attached to Wye College, Kent, which will include problems of the West Midlands hop growing areas, hitherto undertaken by Long Ashton, in its programme of research.

The future of willow research at the Institute has not so far been decided and until a decision is reached the position must remain unsatisfactory. It is hoped that an officer will be appointed by the Ministry of Agriculture, who will be stationed at Long Ashton to act both as a research worker and an adviser to the industry. This arrangement would be identical with that in operation prior to the war and should meet the situation adequately.

Members of the Institute will wish mention to be made in this report of the award of C.B.E. in the Honours List of January 1st, 1948, to our Chairman, Captain Douglas M. Wills. As chairman of the Executive Committee of Somerset W.A.E.C. during the war and until the end of 1947 Captain Wills played a leading part in increasing agricultural production and earned the good will and gratitude of the farming community in the county and of his colleagues on the County Committees. His services to Long Ashton have also been great and at the present time he is Chairman of the University Agricultural Committee and its Finance and Business Sub-Committee and Chairman

of the Governing Body and Treasurer of the National Fruit and Cider Institute. All connected with the Station, including the Governors and Members of the Institute, members of Committees and the staff, will wish to congratulate Captain Wills on this well merited award and to convey to him their good wishes on this happy occasion.

During the year it was learned with regret that Mr. Ivor Fox, Bursar of the University, had resigned his appointment due to ill-health. Mr. Fox had for many years played a very active part in safeguarding the finances of the Institute and it was in great measure due to his advice on financial matters and his detailed attention to the accounts that the finances of the Department, including the Research Station and the Berkeley Square Advisory Centre, remained sound during the difficult years prior to and during the war when research and advisory work were expanding rapidly. The Committee and staff join in hoping that Mr. Fox will enjoy greatly improved health in his retirement.

Financial provision for research work during the year was adequate, the only obstacle in providing for research being the difficulties and delays in obtaining apparatus and other materials.

It is pleasing to be able to report a further increase in the number of members in spite of the curtailment in the direct advisory services of the Station. It may again be emphasised in this connection that the new arrangement allows the staff to give closer attention to research problems whilst at the same time they are available to assist their colleagues in the N.A.A.S. with their specialist knowledge of particular problems. In the long run the new arrangement should bring greater advantages to growers.

Staff.

During the year there were relatively few changes in the scientific staff.

Mr. A. H. Williams was appointed to the post of Organic Chemist under the special Agricultural Research Council grant for mineral deficiencies investigations. Mr. Williams graduated from University College, Oxford, in 1939, and later took up a post with Messrs. Courtaulds Ltd., Coventry, where he carried out researches on cellulose and its derivatives. From 1940-1945 he worked on the chemistry of sulphur and nitrogen for the Ministry of Supply, returning again to Messrs. Courtaulds on the completion of this war-time service.

Mr. J. A. H. Tolhurst was transferred from the Agricultural Research Council Hops Diseases Investigations Scheme to fill the post of Research Assistant in Chemistry from 1st March, 1947.

In addition sanction was obtained during the year for the appointment of a Pomologist to undertake field problems, and of a Plant Physiologist to work with the Plant Pathologists but, so far, it has not been possible to obtain suitable applicants for these posts.

At the suggestion of the Agricultural Research Council, Mr. H. Gleen, a member of the Council's team of research workers on soil metabolism, under Dr. J. H. Quastel, previously stationed at University College, Cardiff, was transferred to Long Ashton on 22nd October, 1947, to enable him to continue his work in association with the Long Ashton staff engaged on A.R.C. mineral deficiency investigations.

Other appointments to the assistant staff were as follows :

Mr. W. J. Redmond as Analyst under the Agricultural Research Council Mineral Deficiencies Scheme from 8th December, 1947.

Mr. J. H. Llewellyn as Technical Assistant in the Cider Section from 8th December, 1947.

Miss I. Taylor, as Library Assistant from 23rd June, 1947.

During the year Mr. J. Packer, Ledger Clerk, was demobilised from the Royal Air Force, in which he had served since December, 1943. He had been engaged on flying duties as a signaller and held the rank of sergeant. He returned to the Station on 18/8/47 and we were very pleased to welcome him back.

The following resigned from their posts during the year :—

Mr. C. F. Mills, Research Assistant in Chemistry, Agricultural Research Council Mineral Deficiencies Investigations, from 31st August, 1947.

Miss J. Bryan, Research Assistant (Chemistry) in Fruit Products and Cider section from 30th November, 1947.

Mr. W. H. Neild, Horticultural Assistant, from 31st July, 1947.

Miss M. Porter, Assistant Recorder (Willows) from 31st October, 1947.

Mr. A. C. Bunt, Research Assistant (Machinery and Spraying) from 7th July, 1947.

Mr. J. A. Berendt, Assistant Recorder, from 11th August, 1947.

Mr. G. F. Foster, Ledger Clerk (Temporary Worker) from 4th October, 1947.

The special thanks of the Station are due to Mr. Neild and Mr. Foster, both of whom joined the staff from retirement during the war to fill important vacancies.

During the year several important Conferences were attended by members of the staff.

The Director attended, by invitation of the Association Française pour l'étude du sol, la Conférence Internationale de Pedologie Méditerranéenne, held at Montpellier, France—where he read a paper—and in Algeria, in May, 1947. On his return journey he delivered a lecture at the Conservatoire des Arts et Métiers, Paris, under the auspices of the French Ministry of Education. He presided as Chairman of the Section of Agricultural Chemistry and Applied Botany of the XI International Congress of Pure and Applied Chemistry, held in London in July, 1947, at which Conference papers were presented by Drs. Martin, Bould, Plant, Hewitt and Nicholas. He also acted as Chairman of the paper-reading sessions at a Symposium on Trace Elements in Plant Physiology, organised by the International Union of Biological Sciences, held at Rothamsted Experimental Station on November 5th and 6th, 1947. Dr. E. J. Hewitt also attended this symposium by invitation and read a paper. Dr. L. C. Luckwill attended a Conference of the Society for Experimental Biology, held at Utrecht, Holland, on April 10th to 14th, 1947 and later visited research centres and fruit farms in that country. Dr. S. W. Challinor attended the 4th International Congress of Microbiology at Copenhagen from 20th to 26th July, 1947.

Dr. W. D. E. Thomas attended a Summer School on ' Some recent advances in Physical Chemistry ' held at Cambridge from 16th to 23rd August, 1947.

Mr. E. J. Hewitt and Mr. D. J. D. Nicholas were awarded the degree of Doctor of Philosophy by the University in December, 1947, for researches relating to the Mineral Nutrition of Plants.

The Annual Christmas Staff Party was held on December 19th and was attended by 250 members of staff and their friends. The events of the evening included a Whist Drive and two short Plays by members of the staff, followed by dancing. The Plays were much appreciated and great credit is due to all who contributed to the success of these events. Thanks are also due to members of the Station Welfare Committee, who organised the events and also

carried out the large amount of work required in connection with the catering arrangements.

Buildings and Land.

During the year it was possible to complete the painting work on the greenhouses, but unfortunately a portion of the work done on the large plant nutrition house has proved unsatisfactory, due to unfortunate weather effects and must be repainted during the summer of 1948.

Estimates have been obtained for painting all the main buildings on the Station, including the laboratories, cider house and house property, and permits have been received to enable the work to be begun in April, 1948. The Ministry of Agriculture has obtained Treasury approval to share the cost of this work, most of which has been urgently needed for a number of years.

Minor alterations were carried out on one of the greenhouses to convert it into a laboratory in which to house Mr. Gleen. The cost of the alterations will be borne by the Agricultural Research Council.

As previously stated the new Biological Building is likely to be completed during the first half of 1948. The erection of this building, coupled with the normal growth of electrical requirements of the main laboratories and cider house and the likelihood of a further building programme in the near future, has made the provision of a new transformer house necessary and this has been provided by means of a special grant from the Treasury.

Plans have been prepared for a special building to meet the experimental requirements of Cider and Fruit Products. The building has been designed to provide for work on a pilot factory scale and should enable experimental work to be carried out under the conditions required for the best factory practice. It is hoped that this building will be erected at a very early date since it will be impossible without it to carry out the experimental work contemplated under the new scheme of research on cider and fruit products.

Another small building is proposed in connection with the scheme of pot culture experiments to provide facilities for the preparation of pots and sand. These experiments are now carried out on a large scale and methods have been evolved for preparing pots and sand to meet the increased requirements. Unfortunately no suitable building is available and a very special structure is necessary. Plans for a suitable building have been prepared, and in view of the importance of this work and the success already achieved, it is to be hoped that the building will be available in the very near future.

During the year a small hut on the Station property belonging to the Royal Observer Corps was purchased and removed to a site on Plot 23 to house plantation equipment. In the cider cellar a new Ebon-lined concrete tank of 1,300 gallons capacity was fitted to replace a faulty 1,000 gallon wooden vat. It is proposed eventually to fit other tanks of this and other types in the cellar to provide for storage requirements.

A beginning was made with the planting of post-war experimental fruit plots during the autumn of 1947 when $3\frac{1}{2}$ acres of apples were planted on Plot 24 for an experiment to compare planting distances and planting systems for apples. The remainder of the plot and an adjoining field have been ear-marked for experiments with plums and the trees for these are now being prepared in the Station nursery.

It has also been decided to extend the planting of bush cider trees on the farm in order to compare the relative suitabilities of various methods of manage-

ment and the performance of certain recommended varieties as bush trees. For this purpose it will be necessary to utilise some of the land at present farmed by Mr. Butler, who has been informed of our proposals and notified regarding the particular fields required for the work.

Mr. Butler has continued his tenancy of the outlying portions of the farm.

During the year the willow plots were maintained but the position regarding these has been rendered difficult by the resignation of Miss M. Porter, the Willows Recorder, at the end of October, 1947, and the lack of a decision on the future of the work. The appointment of a successor to Miss Porter has been postponed pending this latter decision and in these circumstances it is difficult to attend adequately to the routine operations necessary on the plots.

The lawn adjoining the laboratories was re-seeded during the autumn with a view to re-establishing the grass tennis courts which became neglected during the war. The re-opening of the courts for play will be greatly welcomed by the staff since no other facilities for recreation exist at the Station.

The bush cider plots, under the new cultural and manurial treatments, are already yielding data of practical interest and during the next few years they should prove of great value and interest to cider fruit growers. On the occasion of the Cider Conference in Bristol the plots were used to demonstrate the action of a mobile spraying unit for plantations of this type.

The yields obtained in the manurial experiment on black currants have provided interesting information on the relative values of dung, sewage sludge and composts as sources of available nitrogen for black currants. They showed that both dung and composts are relatively inefficient suppliers of nitrogen and need to be supplemented by more active sources of the element to produce the best results. Sewage sludge, by comparison, gave satisfactory yields comparable with nitro-chalk and meat meal.

The 1947 season was notable in tree fruits for the prevalence and intensity of attacks of red spider and this enabled data to be obtained relative to the effects of spraying systems on the incidence of the pest. Heavy infestations followed applications of D.D.T. and where this material had been used in the Station cider orchards to test its efficiency as a substitute for winter washes in controlling aphids and other pests the effects of spider were devastating.

The season was also a very difficult one from the viewpoint of work on the farm. The abnormally hard winter, extending well into March, held up the winter and early spring work, and spring cultivations and plantings were impossible due to the wet state of the land.

Later the short blossoming season telescoped spring spraying operations and this was followed by conditions which produced early maturity in the various crops. The abnormally dry autumn also prevented late cultivations and autumnal plantings. In spite of all the difficulties resulting from these conditions the farm work was kept well in hand and successful crops harvested. Blackcurrants, in particular, yielded heavily, but the cropping of apples was very irregular, as in most West Country orchards.

Research Activities.

In the investigations on the mineral nutrition of crops preparatory work was carried out in the field to establish centres for intensive studies of problems of soil acidity, lime-induced chlorosis and various mineral deficiencies and toxicities. One acidity trial on potatoes was continued at which the reactions

of six varieties under lime and fertiliser treatments were studied. The results showed that the varieties reacted differently to the different nutritional conditions. A number of potato species were also tested for their reaction to strongly acid soil conditions.

In the pot culture experiments some notable advances were recorded. A new technique for studying the effects of molybdenum deficiency in sand cultures was tested and it was found possible to produce acute deficiencies of the element in cauliflower, savoy, mustard and tomato, thus proving that molybdenum is essential for these four plants. A feature of the technique is the purification of nutrient salts from molybdenum by precipitation with 8-hydroxyquinoline and a ferric salt. The result with cauliflower promises to have an immediate practical application in solving the problem of ' Whip-tail ', a trouble causing serious losses in cauliflower and broccoli. If this trouble is controlled by molybdenum applications, the larger problem of molybdenum deficiency in other crops will be opened up : for example, the possibility that this is a cause of clover failures in hill areas and the probability of the deficiency occurring in certain peat soils.

Further experiments on the inducing of iron deficiency by heavy metal compounds has shown that an explanation of this phenomenon on the basis of oxidation-reduction potentials of the simple kations is untenable. The order of activity of a number of ions was as follows : $Co^{++} > Cu^{++} > Zn^{++}$ and $CrO_4 > Ni^{++} > Cr^{+++} > Mn^{++} > Pb$.

The ions also produced distinctive toxic effects, the order being $Ni^{++} > Co^{++} > Zn^{++} > Cu^{++} > CrO_4 > Cr^{+++}$ Mn and Pb (Nil).

Problems of iron/potassium relationships were further studied and it was shown that the level of potassium affected the visible effects of iron deficiency. Thus, when potassium was low, iron deficiency effects were pronounced at the tips of shoots and when high the chlorotic symptoms were milder but were more generally distributed over the foliage. In acidity studies further evidence of the relative effects on different crops of calcium deficiency, manganese and aluminium toxicities and pH have been obtained. Sugar beet and barley were shown to be particularly sensitive to aluminium toxicity, oat being less affected than barley : Brassicae, including cauliflower, marrow stem kale and swede and also potato were relatively tolerant to aluminium. Brassicae were highly sensitive to manganese toxicity, oat and sugar beet being less so. Kale, cauliflower and potato were all sensitive to calcium deficiency. The protective action of calcium against manganese toxicity was confirmed.

The tissue test method was further developed and applied to numerous crops. The seasonal cycles of extractable nutrients have been determined for a number of crops on special field plots and as a result the precision of the method has been increased. Tests have been adopted for the detection of excesses of a number of heavy metals in plant tissues, including Cu, Zn, Pb, Cr, Ni and Co. The distribution of boron in plant tissues is under examination and methods are being studied for the differentiation of mobile and immobile boron and iron in tissues. Methods for the estimation of available Mg, Zn and Cu in soils, using a strain of *Aspergillus niger* supplied by Dr. E. G. Mulder, Groningen, Holland, are under trial. Mulder's method for Mg has been modified by pre-treating the soil before adding to the media and with this innovation appears promising. A reliable method for detecting low Mg status when potassium is deficient is urgently needed and results already obtained with the *Aspergillus* method suggest that it may be suitable for this purpose.

Field trials combined with tissue tests have shown that thiosulphates

when added to the soil may increase the availability of Mn to the plant without lowering the pH of the soil.

In experiments to test the effects of cover crops and manurial treatments on apples, a rye grass cover has increased fruit yields and raised the potassium status of the soil. On black currants, stable manure and sewage sludge/straw composts have reduced cropping by lowering the nitrogen status of the soil, whilst uncomposted sewage sludge has proved an excellent source of nitrogen and has given yields similar to nitro chalk and meat meal.

Experiments on the control of Mg deficiency in apples and broccoli have shown the advantage of foliage spraying treatments over soil applications. At one centre, where Mg deficiency is acute, no benefit had resulted from three annual dressings of magnesium sulphate at 5 cwt. per acre, whereas in one season, considerable response was obtained from five fortnightly sprayings with 2 per cent. Epsom salts starting at petal fall.

Previous experiments with fertilisers on fruit trees have shown the difficulty of obtaining quick responses to certain of the major nutrients applied to the soil, such as potassium, phosphorus and magnesium. In an attempt to speed up these responses a soil injection method is being tested. A special tool, known as the ' Mapic ' injector, which is used in France for this purpose, has been imported for the trials.

Experiments were continued on the growth promoting substance which occurs in apple seeds and which can induce parthenocarpy in tomatoes. Its distribution in the various parts of the seed was measured and it was found to be largely concentrated in the endosperm. From the season's experiments it seems that the function of this hormone in the apple is to prevent abscission of the fruits.

A method of estimating growth substances inducing parthenocarpy has been developed, based on the measurement of their effects on the tomato ovary. The method was used successfully in studying the hormone content of developing apple seeds.

In the examination of materials for inhibiting the sprouting of stored potatoes methyl-l-naphthyl methyl ether was found to be more effective than methyl-α-naphthalene acetate.

Arising from the plant breeding investigations, a considerable demand exists for propagating material of Mr. Spinks' pears Bristol Cross and Cheltenham Cross, the late plums, Thames Cross and Severn Cross, and the three black currants, Mendip Cross, Cotswold Cross and Malvern Cross. The present fruit breeding programme includes as important items crosses made with the object of improving varieties of cider apples and of raising black curran t with a high content of vitamin C.

In Plant Pathology, tests have been made with certain of the insecticides developed in Germany in 1940-45. It was shown that small quantities of a dilute solution of bis-(*beta*-fluoroethoxy)-methane, when watered on to soil were taken up by plants growing in that soil and rendered all parts of these plants insecticidal for some weeks. Systemic insecticides of this type cannot be used in commercial horticulture because of their intense toxicity to man, but such materials promise to be of great value in the study of translocation in plant tissues.

Results of trials of some of the newer organic fungicides on apples and black currants were collated for publication. Preliminary tests were made of the use of growth-promoting substances in the treatment of apple canker; and investigations were started on a new apple disease characterised by branch swellings

and fissuring of the bark. In the work on pest control machinery, special attention was paid to the development of 'automatic' mobile spraying outfits.

In the Cider section much interest has again been taken in the trials of bush cider trees and it is obvious that this method of production must be fully explored. At the present stage of the investigations many problems of management require examination with a view to simplifying operations and keeping the costs of production at a low figure.

Orchard surveys are in progress in the main cider producing areas with the object of assessing potential supplies of fruit. During the year attention was given to the West Worcestershire area. Further descriptions of cider varieties have been made towards the preparation of a monograph on English Cider Apples.

In laboratory investigations the possibilty of applying chromatographic methods of analyses to ciders and fruit juices is being examined. Preliminary experiments indicate that the method will be of considerable use for the separation of a variety of constituents including sugars, pigments and tannin and acid fractions.

The vitamin contents of fresh fruits, including apples, black currants and tomatoes, and the retention of vitamin C in various fruit juices have formed the principal subjects of study on fruit products. Work has also been continued on the quality of potatoes, including liability to blackening on cooking and the results have confirmed the importance of site effects in determining quality.

The work on domestic preservation of fruit and vegetables has included a study of the retention of ascorbic acid in preserving products in relation to methods of preparation and storage. In a survey of the vitamin B_2 content of fresh fruits, twenty-five varieties of fruit have been assayed, using a microbiological technique for nicotinic acid, biotin and pantothenic acid.

Annual Field Day. The annual field day for members was held on July 10th, in combination with the Annual Meetings of the Governors and Members of the National Fruit and Cider Institute. Members were able to see much of practical interest during the day in the form of extensive exhibits in the laboratories and in the pot culture enclosure and plantations.

A special demonstration was also organised in connection with cider orcharding problems on October 14th, 1947, on the occasion of the Cider Conference in Bristol, at which methods of general management of bush plantations and the use of an automatic spraying outfit were shown.

Cider Sampling Day. Following the post-war custom a special cider sampling day was held on Thursday, May 8th. On this occasion the special subject chosen for demonstration was the principles of blending ciders. This subject was selected in view of the low quality of the juices from the 1946 crop and it was shown that even with these exceptional juices attractive beverages could be produced by judicious blending.

Visitors. Organised parties during the year numbered 61, which represents an increase of 7 over 1946. They included 6 parties from abroad as follows: Danish editors, Hungarian agriculturists, French farmers, Dutch horticulturists, four West African Chiefs and German youth leaders. Other parties from Great Britain requiring special mention were Advisory Specialists of the National Agricultural Advisory Service (Fruit and Vegetable Specialist Groups) and National Agricultural Advisory Service Officers of the S.W. Province; Members of the Institute of Corn and Agricultural Merchants; Joint Sections (S.W. area) of the Chemical Society, Royal Institute of Chemistry

and Society of Chemical Industry; Horticultural Education Association (S.W. Section). The full list is as follows:—

Association of Scientific Workers.
Austrian Agriculturists.
Bridgend and District Horticultural Society.
Bristol Conference on Cider Apples.
Bristol University Botanical Society.
Bristol University Education Students.
Bristol University Microbiological Students.
Bromsgrove Growers.
Burderop Park Training College, Swindon.
Clifton College Young Farmers' Club.
Coleford Branch of Workers Education Association.
Colston's Girls' School. (2).
Danish Editors.
Devon Fruitgrowers.
Dutch Growers.
Dutch Students.
European Visitors taking Course at Somerset Farm Institute, Cannington.
Field Day and Annual Meeting of Members.
Fishponds Diocesan Training College, Emergency Training Group.
French Farmers.
German Youth Leaders.
Gloucestershire Horticultural Post-War Trainees.
Hampshire Federation of Women's Institutes Produce Guild.
Hereford Agricultural Education Committee.
Hungarian Agriculturists.
Imperial College (London) Post-Graduate Students. (2).
Institute of Corn and Agricultural Merchants.
Joint Sections of the Chemical Society, Royal Institute of Chemistry and Society of Chemical Industry.
Kings College, Newcastle-on-Tyne.
Kingswood and Hanham Allotments Association.
Long Ashton Horticultural Society.
Long Ashton Poultry and Rabbit Club.
Lord Wandsworth School, Long Sutton, Basingstoke.
Merchant Venturers' Technical College, Pharmacy Students Association.
Midsomer Norton, Radstock and District Gardeners' Debating Society.
Monmouth Institute of Agriculture Horticultural Students.
National Agricultural Advisory Service Advisory Specialists—Fruit Group.
National Agricultural Advisory Service Advisory Specialists—Vegetable Group.
National Agricultural Advisory Service South Western Province. (2).
Oakley Training College for Men.
Plas Dinam Training Centre.
Portbury Farmers' Discussion Group.
Redland High School.
Shropshire County Branch N.F.U.
Somerset Farm Institute, Cannington—Students.
Somerset Farm Institute, Cannington—Horticultural Students.
Somerset Gardening Teachers.
South Western Branch of Institute of Park Administration.
South Western Branch Horticultural Education Association. (2).
Taunton School Scientific Society.
Theale Village Production Club.
Tisbury and District Young Farmers' Club.
University Employees' Association.
University Settlement 'Over 20' Club.
Weston-super-Mare Grammar School.
West African Chiefs.
W.V.S. Housewives, University Settlement.
Wotton-under-Edge Home Food Production Club.
Worcestershire Federation of Women's Institutes.

The year was notable for the large number of scientists from overseas who visited the Institute. Among these we may mention specially Mr. A. N. Duckham, the Agricultural Attaché to the British Embassy, Washington, U.S.A., Dr. F. J. Nutman, Director of Clove Research Unit, Zanzibar, and Mr. N. E. Holmes, Australian Research Liaison Officer. The other visitors

represented no less than 21 countries and it was a great pleasure to the members of our staff to have the opportunity of establishing so many new contacts and to discuss with their foreign colleagues many problems of mutual interest.

Shows and Demonstrations. With the establishment of the N.A.A.S. the number of exhibits at Shows has been greatly reduced and it is now the policy of the Institute to stage exhibits mainly in collaboration with the N.A.A.S. Under the present organisation, however, it is still necessary to provide special cider exhibits at the large shows and this was done in 1947. The following is the list of shows and exhibitions to which the Institute contributed:—

Royal Horticultural Society—Chelsea Show, May 21st—23rd, 1947.
Bath and West Show—Cheltenham, May 28th—31st, 1947.
Three Counties Show—Hereford, June 17th—19th, 1947.
Royal Agricultural Society's Show—Lincoln, September 3rd—5th, 1947.
Bristol Horticultural Show—Bristol, September 3rd—5th, 1947.
Brewers' Exhibition—London, October 27th—November 1st, 1947.

Research Students and Voluntary Workers. Until further accommodation is provided it is impossible to accept graduate students for higher degrees. It has been possible to take a few workers for short periods during the year both for special laboratory studies and for work with members of the pomological staff in the plantations. Four students have received a course of training in the Cider House. Details are as follows :—

Mr. E. Lush, of Messrs. Boots Ltd., spent four months working in the plant nutrition section.

Mr. E. A. Evans, of the United Africa Company, came for a fortnight to get a general view of the work of the Station.

Dr. D. Mulder, Wilhelminadorp, Netherlands, spent a fortnight with Dr. Nicholas for training in Tissue Test methods.

Miss J. Norman, a student at Royal Holloway College, worked on a voluntary basis in Dr. Challinor's laboratory for a month during the summer vacation and Miss M. Holloway, a student in the Botany Department of the University College of North Wales did vacation work under the guidance of Dr. Luckwill. Messrs. Serge Monet and Alain Brulé, two French graduates, received vacation training in Pomology during September and October. Lieut. Nowakowski, of the Polish Resettlement Corps, spent one month in training in Pomology and Chemistry. Messrs. L. Bishop, R. Clarke, E. R. Langford and K. S. Showering received instruction in cider making during the year.

Three refresher courses for Machinery Officers of the Ministry of Agriculture and Fisheries, were given by Dr. Kearns and Mr. Hoddell.

In the Domestic Preservation section the following courses were given :— One three-week course in Fruit and Vegetable Preservation, including Judging of Preserves. Two fortnight courses in Fruit and Vegetable Preservation only and one short course in Produce Judging. The total number of students attending the above courses was 56. A special course on Fruit and Vegetable Preservation was also given to 12 students from the Bath Domestic Science College. Thanks are due to Miss P. Leicester for helping the staff with these courses.

Mr. H. E. Beviss has continued as a voluntary worker on the Plantations recording staff and sincere thanks are due to him for his valued help.

Acknowledgments. The steady development of the work of the Station during 1947 imposed additional responsibilities on many members of the staff. Particular mention must be made of Dr. Martin's help in shaping the research

programme and in advising on special requirements of equipment and apparatus. Dr. Kearns undertook a major share in supervising the planning and equipment of the new Pathology Laboratories : Miss Crang and her colleagues have again directed the running of the canteen, and Mr. Marsh has dealt with editorial matters. The Library has continued its expansion under Mr. Spinks' charge. Mr. Hobbis, in a year of exceptional weather difficulties, effectively maintained the field programme.

Grateful acknowledgment is also made to all members of assistant and technical staff and employees for their contributions to the achievements of the Station during the year.

CIDER VARIETIES RECOMMENDED FOR POST-WAR PLANTING.*

By B. T. P. BARKER.

The varieties of cider apples to be found in the orchards of the West of England are very numerous. Many are undesirable both in crop production and cider-making qualities. Others are only of average merit and might well be replaced by better existing varieties. A further number, excellent in some aspects, do not always combine the orchard and cider-making qualities desired by farmers and cider makers.

Since the nursery trade cannot be expected to carry stocks of varieties other than those for which an extensive demand is likely, a short general list of recommended varieties has been compiled (see p. 20). The varieties in this list have been agreed by a Committee of representatives appointed by the Long Ashton Research Station, the National Farmers' Union, the National Association of Cider Makers, the National Agricultural Advisory Service and the County Councils of Devon, Dorset, Gloucester, Hereford, Monmouth, Somerset and Worcester.

The list contains cider apples of the three main groups :—Sharps, Sweets and Bittersweets.

At present many cider orchards contain too high a proportion of sharp varieties, and cider fruits are often grown in mixed orchards along with market varieties. Because of the high proportion of acid sorts in the orchards it is considered desirable at the present time to confine planting to sweet and bittersweet sorts to meet the special requirements of the cider-making and apple juice industries.

There does exist, however, a group of cider apples which combine high tannin content with high acidity—the so-called bitter-sharp varieties—which are valuable to many cider makers. A few other sharp varieties of particular merit have also been included. These should only be planted to supply special and more distant needs.

A supplementary list has been added to meet local preferences in the main cider-growing areas.

Some details of orchard characters are appended.

* This article has also been published in *Agriculture*, LV., 113–116 (June, 1948).

RECOMMENDED VARIETIES.

General List.

Varieties valuable for General Planting.

Class	Cider-Making Season		
	Early (September to mid-October)	*Mid-Season* (Mid-October to mid-November)	*Late* (After Mid-November)
Sweet Varieties		**Court Royal** **Sweet Alford.**	**Sweet Coppin**
Bittersweet Varieties	**Bulmer's Norman**	**Tremlett's Bitter** **Yarlington Mill**	**Ashton Brown Jersey** **Dabinett** **Tardive Forestier**
Bittersharp Varieties		**Improved Foxwhelp** **Kingston Black** **Stoke Red**	
Sharp Varieties	**Backwell Red**	**Crimson King**	

Supplementary List.

Varieties Valuable for Local Planting

Local Areas	Class	Cider-Making Season		
		Early (September to mid-October)	*Mid-Season* (Mid-October to mid-November)	*Late* (After mid-November)
Devon	*Sweet Varieties*	Morgan's Sweet		
	Bittersweet Varieties		Ellis Bitter Kingston Bitter	
	Sharp Varieties		Coleman's Seedling	Langworthy
Gloucester Hereford Monmouth and Worcester	*Bittersweet Varieties*	White Norman	Michelin Brown Snout	Fréquin Audièvre Bedan Reine des Pommes Belle Norman
	Sharp Varieties		Frederick (Monmouth)	
Somerset	*Sweet Varieties*	Morgan's Sweet		
	Bittersweet Varieties		Red Jersey Hangdown	Dove

APPENDIX.

Orchard Characters of the Recommended Varieties.

Class	Variety	Blossoming	Harvesting	Remarks
Sweet Varieties	*Court Royal (*Syn.*: Sweet Blenheim)	Early mid-season	Early—mid-season	Vigorous. Similar to Improved Pound
	Morgan's Sweet	Early mid-season	Very early	Vigorous. Good stem builder
	Sweet Alford	Mid-season	Mid-season	Vigorous; not suited to light soils. Susceptible to magnesium deficiency
	Sweet Coppin	Late	Mid-season—late	Vigorous
Bittersweet Varieties	Ashton Brown Jersey	Mid-season—late	Moderately late	Vigorous
	Bedan	Moderately late	Moderately late	Fairly small tree
	Belle Norman	Mid-season—late	Mid-season	Vigorous
	Brown Snout	Mid-season	Mid-season	Moderately vigorous
	Bulmer's Norman	Early mid-season	Early—mid-season	Vigorous. Good stem builder
	Dabinett	Mid-season—late	Mid-season—late	Small tree. Susceptible to potash and magnesium deficiencies. Requires fertile soil
	Dove	Very late	Late	Moderately vigorous. Prefers fertile soil
	Ellis Bitter	Moderately late	Mid-season	Moderately vigorous
	Fréquin Audièvre	Late	Late	Moderately vigorous
	Hangdown (*Syn.*: Horner's; Pocket Apple)	Late	Mid-season	Large tree, tangled head
	Kingston Bitter	Late mid-season	Late	Moderately vigorous
	Michelin	Mid-season	Mid-season	Vigorous
	*Red Jersey	Late	Mid-season	Moderately vigorous
	Reine des Pommes	Very late	Very late	Moderately vigorous. Subject to potash deficiency
	Tardive Forestier	Early—mid-season	Late	Vigorous
	Tremlett's Bitter	Early mid-season	Mid-season	Moderately vigorous
	White Norman	Early—mid-season	Early—mid-season	Moderately vigorous
	Yarlington Mill	Mid-season	Late—mid-season	Moderately vigorous. Very heavy regular cropper

* See footnote on p. 22.

Class	Variety	Blossoming	Harvesting	Remarks
Bittersharp Varieties	*Improved Foxwhelp	Mid-season	Early—mid-season	Moderately vigorous
	Kingston Black	Late mid-season	Mid-season	Recommended for suitable localities only
	Stoke Red	Late	Mid-season	Rather slow in forming head, but ultimately gives "Umbrella" head of moderate size
Sharp Varieties	Backwell Red	Early	Early	Moderately vigorous
	Coleman's Seedling	Late	Mid-season	Vigorous: assumes drooping habit with cropping
	Crimson King (*Syn.*: Bealy Down Pippin; Jackson; King's Favourite)	Mid-season —late	Mid-season —late	Moderately vigorous
	Frederick	Mid-season —late	Mid-season	Moderately vigorous
	Langworthy (*Syn.*: Wyatt's Seedling; Sour Natural)	Mid-season	Mid-season —late	Moderately vigorous

THE COMMERCIAL GROWING OF CIDER FRUIT IN BUSH TREE PLANTATIONS.

By B. T. P. BARKER, E. W. HOBBIS and H. G. H. KEARNS.

INTRODUCTION.

Official figures issued by the Ministry of Agriculture and Fisheries show that during the past fifty years there has been a heavy and continuous decline in the total acreages of farm orchards in the West of England. In the counties of Devon, Gloucester, Hereford, Somerset, and Worcester the figure has fallen from over 116,000 acres in 1895 to less than 58,000 in 1946. This drop has been due primarily to the disappearance of old and worn-out orchards planted in the first half of last century, when there was a boom period during and immediately following the Napoleonic wars: since then the rate of new plantings has failed utterly to keep pace with the rate of loss.

In relation to the cider industry the significance of the decline is serious, for during those years English cider—previously made and consumed mainly on the farm—has developed into a regular commercial article of general distribution throughout the whole country and with increasing export trade. The source of its basic raw material—cider fruit proper—has been hitherto predominatingly the West Country farm orchards: supplies from their dwindling area

* With these varieties it is particularly important to ensure that the correct variety is secured, since there are other sorts also passing under those names. In cases of doubt reference should be made to the Research Station, Long Ashton.

have been steadily diminishing as the commercial demand for the beverage has been growing rapidly. In fact, the use of cull eating apples and the importation of cider fruit from the Continent have become necessary to provide the required output.

However extensive any movement to establish new orchards of the usual standard-tree farm orchard type may be, even if undertaken forthwith, a minimum period of some twenty-five years or so must elapse before any substantial addition to existing fruit supplies can be secured by that system : for standard trees take that time to reach even a very moderate yield per acre.

Hence alternative methods to give earlier crop production have been sought. That of growing cider fruit on bush trees under plantation conditions seemed most likely to meet the requirements for quick crop production combined with reasonably satisfactory economic aspects. The idea of cider fruit production in this manner is by no means new. One of the best-known cidermaking firms established a plot in the early years of the present century, this being probably the first in this country. In 1906 one was planted at the Research Station at Long Ashton. In each case the immediate object was to provide rapid trials of individual cider apple varieties rather than to ascertain the suitability of the method for mass crop production for general cider-making purposes. Nevertheless some information on the latter point was in any event an incidental result derived from the trials.

Unfortunately the site of the Long Ashton plot proved thoroughly unsuitable, being subject to flooding and soil erosion during heavy rainstorms by its location at the base of a long stretch of sloping hillside. Moreover the soil was heavily deficient in potash and the growing trees suffered the usual characteristics of leaf-scorch and associated growth-dwarfing, although the cause of these symptoms was not known at that time. Notwithstanding these drawbacks, the more favourably situated trees on the plot indicated the possibilities of the method for suitable sites and soils.

Claims of higher priority for the use of the rest of the land at the Research Station prevented any further trial there until 1935, when the acquisition of additional land made available a site which was suitable for the purpose. Details of the new plot and of others established at eight other centres at the same time with trees raised at the Research Station are given in a progress report by Swarbrick in the Annual Report of the Station for 1941 (4). The subsequent results for the growth performance of the trees, their crop production and the vintage character of the fruit are given in the Annual Reports for 1942, 1943 and 1945 (5, 6, 7). They indicate that the bush plot system under suitable conditions of site and management is one of great possibilities for quick and heavy crop production of fruit of a high vintage quality : it also shows considerable promise as a sound economic proposition.

Much interest in the method has been shown recently and many enquiries about details of procedure have been received from persons considering planting. There appears therefore a need for a general article on the subject dealing with the application of the knowledge from the trial plots to the commercial production of cider fruit in bush plantations.

BUSH PLANTATION CULTURE.

General.

Sufficient experience in the establishment and maintenance of bush cider trees has now been gained to suggest the lines along which plantings can be undertaken with a reasonable prospect of success. The bush cider plantation,

however, is a complete break away from the time-honoured method by which cider fruit has been grown in farm orchards. It has little in common with the older method and must be looked upon as a special venture.

Cider bush growing, in common with any other form of fruit growing, requires considerable capital expenditure. The satisfactory management requires suitable cultivation and spraying equipment. It is desirable to select an acreage which in full bearing is well within the capacity of the equipment provided. It is suggested that 40 acres would be the most economic size if developed as a self-contained bush cider unit. Where other fruit farm equipment is already available the acreage would be adjusted to suit individual circumstances.

Bush cider trees require a type of culture similar in fundamentals to that found in the commercial dessert or culinary apple plantation with its attendant pruning, spraying, manuring and soil management and all the equipment necessary to carry out these operations. The best height of stem has been found to be 3 ft. which precludes the grazing of stock beneath the trees. The bush cider plantation is therefore unlikely, in the main, to appeal to the farmer, whose circumstances permit the growing only of the standard orchard in grass stocked by cattle ; the trees receiving relatively little attention.

The demand for quantities of cider apples *of the right varieties* seems, however, to be assured for many years to come, and the bush tree, as shown by the performance of the pilot bush plantations, provides the quickest and best means of meeting this demand. The gross returns or profits from cider fruit do not approach those from high-quality dessert apples (second quality cookers often fetch low prices), but as an offset to this the expense of producing, handling and marketing cider fruit is very low in comparison with the heavy costs incurred in picking and marketing high quality apples. The price of cider fruit is generally known well in advance and is relatively satisfactory for the right varieties. Provided that the grower is willing to take a little trouble to ensure that the fruit is harvested and sent to the factory in good condition, harvesting can be a quick and simple affair. No hand picking is required, as the fruit is ready when it falls off the trees. It can be picked up at piecework rates. Marketing is done in hundredweight sacks direct from the plantations and no storage space is needed. The saving of costly handling charges and of capital expenditure on picking equipment, grading, packing and storage facilities is obviously substantial.

The bush cider orchard may be attractive to fruit growers already established, since they could more readily dispose of their cull apples if they could also offer supplies of low-acid cider fruit. It may also appeal to the landowner seeking a project that will appreciate in value as an estate venture. To others, such as retired Service men with limited knowledge and experience of fruit culture, it provides an opportunity of a career in fruit production as specialist cider fruit growers needing considerably less capital outlay and detailed attention than high-quality dessert apple production.

Type of Land. Apple trees do not need " rich " land but they do require a deep rooting medium which is reasonably well drained. Gently sloping land with lower areas below provides a measure of air drainage and so lessens liability to frost damage. Steep slopes are not suitable.

Varieties.

Since cider apples proper are in very little demand at present for purposes other than cider-making—the new apple juice industry and the commercial

mincemeat manufacturers being the only other users in material quantity—and since there is in prospect no further major outlet for the fruit, it is of prime importance that the grower should confine his selection of varieties to those known to be most needed by commercial cider-makers. These are the sweet and bittersweet varieties—especially the latter—for, being of very low acidity, they are essential to blend with and counteract the very highly acid cull apples which have to be used for cider-making in this era of scarcity of genuine cider fruit. There are a few outstanding exceptions to this generalisation, such as Kingston Black—in districts in which it will make a healthy and profitable tree—but in this case the vintage quality of the variety concerned is of such a high grade that the fact that it belongs to the acid class of apples becomes secondary in importance.

Swarbrick's report, mentioned earlier in this paper (4), gives the names of 21 varieties which have been under test in the bush plot trials established by the Research Station at various centres in 1935. Every variety selected merits its place in respect of its inherent vintage quality. The primary objects of the trials therefore were (a) to ascertain for each variety the nature of its performance as regards growth and cropping when grown in bush form on Malling II and Seedling Crab Rootstocks and (b) to note the effects, if any, on vintage quality of the bush method of culture.

On the former point it is already clear that cider apple varieties in general behave very similarly to dessert and culinary varieties when the orchard performance of trees in the standard and bush forms is compared. No marked difference in the natural habit of growth of a variety has been noted, although size of tree and rate of growth are affected by the nature of the rootstock. The rootstock also influences the period of life at which the tree comes into bearing: and the bush type is also considerably earlier than the standard. The relative crop production of individual varieties is closely parallel, whether the trees are of the bush or standard form.

Thus, although relatively few of the almost innumerable cider varieties have as yet been tested under the bush system, it seems justifiable to assume that those yet untried will respond similarly. This point is important at the present juncture because some of the cider varieties recommended for general planting (1) have not yet been tested in bush form. The other point of outstanding importance already established is that the crop yield per acre of the individual varieties when grown in bush form on plots in their twelfth year after planting exceeds considerably those of the same varieties grown on standard trees more than three times that age: the relevant data are given in papers by Stanton (3) and Savidge (2).

In respect of the effects on vintage quality the ciders produced from the bush-grown fruit have almost invariably been of a high order of merit for the respective varieties concerned: in many instances they have been outstanding. Even when allowance is made for the fact that the vintage tests have been carried out under more favourable and better controlled conditions than those associated with normal cider production on a larger scale in the ciderhouse, the results have been striking and afford conclusive evidence that vintage quality is not impaired in bush-grown fruit. The indications are that it is relatively improved, because the available evidence on the vintage quality of fruit grown on standard trees is that quality improves with the age of the tree at least up to the time of reaching its maximum size: the rapid growth during its years of youth until nearing its prime tends to yield juices of relatively high nitrogen content and accordingly rapid rates of fermentation.

In view of the results it is evident that from the variety standpoint there is an exceptionally strong case for the bush system of culture.

As regards the selection of individual varieties to plant, reference should be made to the list of recommended varieties referred to above (1), which include details of the vintage characters and seasons of blossoming and harvesting, with other relevant points.

In making a selection intending growers should bear in mind any special local requirements and also the type of land. For instance if the farm is subject to Spring frosts yet is otherwise well suited to the growing of apples a selection could be made of late flowering varieties only, e.g. Yarlington Mill, Dabinett, Medaille d'Or and Reine des Pommes. These planted together should provide for effective cross pollination and since they flower relatively late (end May to early June) they generally escape serious frost damage. Such a plantation too would consist wholly of late harvesting varieties.

Rootstock. Cider bush trees must be well anchored. Most of the favoured varieties make large heads in a comparatively few years and since a minimum of thinning out only is given in the way of pruning, the tree heads provide a big surface resistance to wind. Strong growing rootstocks therefore are generally recommended and observations at Long Ashton and elsewhere show that there is very little delay in the time of cropping when using vigorous stocks as compared with the performance of the more dwarfing layered rootstocks.

Crab C and Malling Type XVI, both vegetatively raised rootstocks and therefore uniform in performance, make satisfactory trees, although M XVI is somewhat prone to Woolly Aphis attack. Selected seedling crab is also a satisfactory rootstock and can be recommended with confidence.

Pollination. Little is known, as yet, of the self-fertility or self-sterility of cider apple varieties. Until more detailed information is available, it is advisable to assume that they all set better and bigger crops when cross-pollinated and for this reason three varieties flowering at approximately the same time should be planted relatively close to one another.

The best arrangement is to plant each variety side by side but in a block of not more than four rows, the blocks being repeated across the field if acreage permits. The variety and blossom period tables published with this report (1) will help the intending planter in working out suitable planting schemes.

Spacing. The bush trees should be established in arable land and grassed down in the 5-6th year after planting. The traditional type of bush tree may be grown at a planting distance of 36 feet on the square. A second method, in the experimental stage, consists of growing trees in the form of a "hedge-row", the rows 36ft. and the bushes in the row 18ft. apart. The first method requires 33 trees and the second 66 trees per acre. The second method permits "automatic" spraying to be used with considerable saving in cost of material and labour, items that cannot be lightly ignored, as spraying is the greatest annual expenditure.

The land between the trees could be cropped with potatoes, roots or other summer crops to gain some return in the early years. No attempt however, should be made at overall cropping since this would inevitably lead to moisture robbing in the summer and damage to the tree stems by cultivating or harvesting equipment. In the first year crops should be kept a yard away from the trees on either side and the distance should be increased by a yard each year until undercropping is abandoned in about the fifth or sixth year.

When it is not essential for economic reasons to obtain an immediate cash return it would be better to dispense with any form of undercropping.

Staking and Protection. Each tree should be staked, tied and protected from rabbits and hares by a collar of wire netting at the time of planting. The stake should last at least five years after which the majority of trees should be firmly anchored on their own roots.

Cultivations. Arable. Apple trees establish themselves quickest under arable soil conditions. The site therefore should be clean and deeply worked prior to planting and a clean tilth should be retained around the trees in the early years.

Once the trees are established, say from the fifth or sixth year, the best policy is to grass down and maintain the plantation in a permanent sward which is kept under control by regular mowing.

Grass. A grass cover has many advantages over arable cultivation. It provides a means of replenishing and building up organic matter reserves in the soil; it avoids root disturbances; it hardens growth and reduces the incidence of canker; it greatly facilitates spraying operations and it provides a clean surface on which fruit can fall and from which picking up can be done cleanly and quickly.

Mowing by gang mower throughout the growing season—say, seven cuts—is the most satisfactory method of grass management. The running of poultry, systematically folded through a plantation, provides an alternative, provided that it is carried out in conjunction with the use of a gang mower.

Gang mowing can only be carried out if the grass is not taller than six inches and if for any reason the grass becomes longer it can only be cut with the hay type of cutter bar mower before return can be made to gang mowing.

It is desirable to gang mow at the latest date before fall of the fruit as the short grass facilitates harvesting. The date of fall of the fruit should be considered in the lay-out of the varieties as it is a great convenience and saving in labour to arrange a continuous and orderly harvesting programme.

Gang mowing should be carried out immediately after harvesting if necessary to avoid the necessity of using a cutter bar mower for the first mowing in spring.

Manuring. Adequate manuring should be given from the start, particular care being given to the potash and nitrogen supply, and dressings should be given annually. Where undercropping is practised the manuring given to the undercrop should be supplemented by a special dressing given around the trees.

Pruning. One- or two-year-old trees are recommended for planting. Leader pruning should be reasonably hard for the first two years to achieve a strong and well disposed branch formation after which pruning should become of a generally lighter character each season. Unwanted laterals should be cut out for a year or two after which the main limbs should be allowed to furnish themselves freely with lateral growth which is subject to a light thinning out and regulation to prevent overcrowding. The spurring of laterals should not be attempted.

According to tree response and development it should be possible to dispense with leader-tipping altogether in about the sixth year after planting.

If the " hedgerow " system is used it is desirable to remember that the efficiency of " automatic " spraying lessens with the depth and density of the " hedgerow ".

PEST AND DISEASE CONTROL.

Bush cider trees are planted with the object of obtaining high yields of fruit as early as possible in and throughout the life of the orchard. This object

can only be achieved with many of the varieties by carrying out a regular spray programme. The production of fruit free from blemishes is of little consequence provided the blemishes are not accompanied by insect or fungus attack that will reduce weight of crop either directly or indirectly by interfering with the health of the tree. The spray programme need not therefore be so comprehensive as is necessary for the production of high quality dessert apples. The cost of spraying is the greatest yearly expenditure and therefore it is important to reduce the costs of material and labour by growing the bushes in a manner and of an acreage that permits of the most economic application.

The data on the liability of cider varieties to insect and fungus attack is a subject of controversy and is often based on observations on old trees which are not typical of the conditions likely to be met in a bush cider orchard. In an old unsprayed orchard the trees are usually covered with lichens and they make very little new annual growth and therefore do not offer the conditions for the rapid build up of such pests such as leaf curling aphides and capsid bugs. They are subject from time to time to devastating attacks of Winter Moth. In many cases the trees should be capable of carrying considerably heavier crops and this has been shown by the dramatic increase in yields following winter washing with tar oil and D.N.C. petroleum winter washes. Prior to the 1939-45 war the acreage of cider orchards sprayed was so small that for all practical purposes it made no contribution to increasing crops. During the war some 2,000-3,000 acres of cider orchards were sprayed each year by contract and this acreage represents only about 5 per cent of the total acreage in the country. Nevertheless the acreage sprayed demonstrated clearly that in many orchards the yield was at least doubled. It was also noted that once an orchard was sprayed the increase in vigour was accompanied by an increased susceptibility to insect attack. On the other hand, some varieties, those that broke flower bud very late, i.e., 2-4 weeks later than the majority, were almost free from insect attack (excluding Fruit Tree Red Spider). This resistance was due to the fact that the eggs of aphides, apple sucker and Winter Moth hatch 2-4 weeks before there is any vegetative tissue for them to feed on. In this group of resistant varieties may be included Medaille D'Or, Royal Jersey, Stoke Red, Cherry Norman, Harry Masters Jersey, and Yarlington Mill. In many seasons these varieties also escape attack from Apple Blossom Weevil. Occasionally appreciable attacks of Winter Moth occur on these late bud burst varieties and in each instance it was due to "larvae" blown from infested trees.

The knowledge of resistance to insect and fungus attack on cider varieties is insufficient to warrant planning a planting programme to avoid spraying. Further the resistant varieties do not necessarily possess other desirable qualities from the viewpoint of the cider maker. It may ultimately prove possible to recommend highly resistant varieties for planting of standards in farm orchards leaving the more prolific and best vintage varieties for planting in specialised bush orchards which can be economically sprayed.

Spray Programmes.

(a) *At planting out.*

The nursery stock should be dipped in 10 per cent tar-oil petroleum wash (minimum percentage of tar-oil for aphis control and 5 per cent petroleum oil Grade E) or a wash of equivalent ovicidal properties. The dipping should be carried out in a manner that permits of rapid drying of the wash on the bark. The bushes should be planted within a few days after dipping or alternatively heeled in temporary quarters.

(b) *First season.*

Young trees are subject to attack of Permanent Apple Aphis and in some districts to wind-born larvae of the Winter Moth. Wood infection by Apple Scab must be prevented. A combined insecticidal-fungicidal wash should be applied at a stage that coincides with the full pink bud stage of the mid season flowering varieties. A wash of the following formula is recommended : –

Pink bud stage : 2 lb. lead arsenate powder.
2 gal. lime sulphur.
100 gal. water.

Petalfall stage : 8 fl. oz. nicotine (95–98%)
1 gal. lime sulphur.
1 qt. Estol " H " or 1 lb. sulphonated lorol wetter
100 gal. water.

(c) *Second and subsequent seasons* :

(1) Dormant stage .. D.N.C. petroleum wash.
(2) Pink bud stage .. 2 per cent lime sulphur.
(3) Petalfall stage .. 1 per cent lime sulphur with a wetter.

Notes.

The D.N.C. petroleum wash must be applied at a concentration of 0·1 per cent D.N.C. and 5 per cent grade E petroleum oil, i.e. 7½–8 per cent of proprietary washes. The wash should be applied after Christmas and preferably in late February and in March to ensure the maximum results : applications should be made under climatic conditions that ensure rapid drying of the wash and the minimum of drift.

At petalfall the addition of a wetter to the lime sulphur is important to ensure a satisfactory degree of control of Fruit Tree Red Spider. One quart of Estol " H " or 1 lb. of sulphonated lorol per 100 gals. wash is necessary.

Two pounds of lead arsenate powder should be added to the pink bud stage lime sulphur if Winter Moth and other leaf eating larvae are prevalent.

Modifications.

Every fourth season D.N.C. petroleum wash should be replaced by a tar-petroleum wash applied at 10 per cent concentration as recommended for the dipping of nursery trees (see (a)). Alternatively a wash of similar or greater ovicidal properties to the tar petroleum may be used. This procedure will ensure a satisfactory control of Apple Sucker.

In the event of Apple Blossom Weevil causing more than beneficial thinning of the blossom a D.D.T. wash may be added to the D.N.C. petroleum wash. The wash should be applied not more than two weeks before bud burst of the earliest variety.

If through adverse climatic or other conditions winter washing is omitted, a D.D.T. petroleum wash containing 0·05 per cent D.D.T. and 5 per cent oil should be applied at bud burst of the earlier varieties. This wash will provide a control of the normal range of pests controlled by the above mentioned winter washes and in addition Apple Blossom Weevil and Tortrix Moth species. It must be applied in a manner to ensure complete wetting of all buds.

Occasionally Apple Sawfly attacks varieties that flower at a time coinciding with the dessert variety Worcester Pearmain. Should the infestations increase annually and cause appreciable loss of crops, nicotine at the rate of

8 fl. oz. should be added to the lime sulphur petalfall wash. The wash must in this event be applied within 10 days after 80 per cent of the petals have fallen on the susceptible varieties.

Some varieties at petalfall and in some seasons are subject to appreciable lime sulphur scorch. It may be necessary to avoid spraying these varieties at this stage. In some cases of sensitivity that increases annually it may be a symptom of a manurial deficiency. Highly sulphur sensitive varieties are best omitted from plantings as differential spraying is troublesome and interferes with the easy working of automatic spraying machines. Cider varieties are from time to time, though considerably less so, subject to other pests and disease that occur on dessert and culinary varieties. The methods of control successfully used on these varieties are equally applicable to cider.

Methods of Spraying.

The normal standard cider tree is the most difficult target to spray effectively and considerable unavoidable waste of wash occurs on account of the height and density of the trees. It can only be sprayed in asatisfactory manner by a manually operated lance with considerable output of wash, say of 8–10 g.p.m. at 400 lb. per sq. in.

The bush cider tree during the first 10–15 years is an easy target for manually operated lances. As the trees, due to wide planting distances, become larger the difficulty and expense of spraying increases.

A spraying machine of the tractor trailer type with a pump output of 17–20 g.p.m. at 400–600 lb. per sq. in. and a tank of 300 gallons capacity drawn and driven by a tractor is necessary for a bush cider plantation of 25–40 acres. When the trees are 15–20 or more years old, only the smaller acreage can be sprayed during the growing season.

This type of outfit if used with spray lance brooms requires a team of three men and it will apply 1,500–2,000 gallons per day depending on the weather and local conditions. If the trees in the rows are sufficiently compact to form a " hedgerow " they may be sprayed with an " automatic " spray machine of suitable design which applies the wash as it passes between the rows of the trees. This type of machine only employs one operator and if of adequate pump capacity it not only saves considerable time in application but also volume of wash. A pump of 35 g.p.m. output is desirable to obtain the full advantage of this system, but the smaller pump with an output of 20 g.p.m. may be used, still providing a considerable saving in expenditure of spraying. Another advantage of automatic spraying is the reduction in manual toil associated with lance spraying. Automatic spraying requires care in the choice of suitable spraying days to avoid excessive drift, and the ground conditions should be suitable for heavy mobile equipment. As spraying constitutes the greatest yearly expenditure of cider bush orcharding the advantages of fully mechanised spraying cannot be overstressed.

EQUIPMENT REQUIRED FOR 40 ACRES.

The equipment required in the early years of the life of a planned 40-acre orchard will vary according to the method and rate of establishment. The first five years will involve management of arable land either with or without intercropping. From the sixth year onwards the soil management will change from arable to grass. From the tenth year onwards the trees become rapidly larger and require larger spraying equipment. The pre- and post-blossom spraying also coincides with grass cutting and therefore tractor power must

be available for both operations, as neither can be delayed. Once the grass is established the principal items of management comprise spraying, grass cutting harvesting, manuring and pruning.

The more expensive items of equipment will be as follows :—

First five years (*arable cultivation*)

(1) One 17–20 H.P. rubber-tyred wheeled tractor with integral hydraulically operated equipment.
(2) One two-furrow general-purpose plough.
(3) One spring tine cultivator.
(4) One 7 ft. disc harrow.
(5) One 2-wheeled low-load tractor-trailer.
(6) One 17–20 g.p.m. 300-gallon tractor-drawn and -driven spraying machine.
(7) Provision of adequate supply of water for spraying.

6*th*-10*th years* (*grass cultivation*)

(8) One 17–20 H.P. tractor similar to (1).
(9) One 3 or 5-bank gang-mower on rubber tyres.
(10) One 5–7 ft. cutter-bar mower with integral fitting on the tractor.
(11) One 16 ft. smooth or ring tractor-roller in three sections.
(12) One centrifugal tractor-drawn artificial manure distributor.

11*th year onwards*.

(13) Conversion of spraying machine to " automatic " or preferably sale of sprayer and purchase of (14).
(14) Automatic sprayer with a tank capacity of 400–500 gallons and a pump delivery of 35–40 g.p.m.
(15) Sale of one 17–20 H.P. tractor and purchase of large tractor capable of hauling or hauling and driving automatic sprayer.
(16) Installation of adequate supply of water for spraying.
(17) One 2-wheeled low-load tractor-trailer.
(18) Provision of suitable out-door temporary storage and loading facilities for the fruit from trailers into lorries.

SUMMARY.

The growing of cider fruit on bush trees is considered the only practicable method for meeting the present need for a rapid increase in the home production of vintage cider apples.

It is suggested that bush cider fruit production should be undertaken as a specialised branch of horticulture. While the gross returns per acre from a bush cider plantation will be below those from dessert apple growing, the costs of management, picking, marketing and storage will also be much less.

Recommendations are given for the methods of establishment and maintenance of bush cider plantations, including the requirements for pest and disease control. The more important items of equipment for a 40-acre plantation are detailed.

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THE PRODUCTION OF CIDER FRUIT ON BUSH TREES : OBSERVATIONS ON YIELDS, 1941-47.

By W. R. STANTON.

INTRODUCTION.

This report deals with the behaviour of certain cider apple varieties grown as bush trees in a series of seven trials at widely-separated centres started in 1935-36. (An eighth trial, at Bere Alston, was abandoned in 1939). The total number of varieties represented in these trials is thirty-three, of which seven occur at all the centres.

Progress reports describing the sites, varieties, growth and early cropping records are given in the Long Ashton Annual Reports for 1941 (4) and 1942 (5).

The intervention of the war prevented the continuation of detailed observations, and the taking of actual crop weights could not be resumed until 1946. Estimates of yield however, were made at some or all the centres in 1941, 1942, 1944 and 1945. It is recognized that an estimate of yield of an apple tree, especially when made several weeks before the maturity of the crop, can only be an approximation, which will vary with the observer. But, in the absence of better data, the figures presented will indicate the behaviour of the varieties as bush trees. It will be noted that there are many similarities between the order of yields given below and those of the same varieties as standard trees in Hereford, reported by Savidge (3).

METHODS OF ASSESSMENT.

In assessing the yields of varieties of apples it is as important to know the size of the crop in relation to tree size as to know the actual weight of the crop per acre with the given planting distance. Fortunately it is possible to assess the relative yield more easily than the actual crop weight, and in Table I the terms for crop size in common use are listed and allotted numerical values on an arbitrary scale of 0—10. These values, which are termed relative yield figures, are used for subsequent computations in this paper.

RESULTS.

The main effects considered are :—

Varieties.

The figures given on p. 33 are for the mean estimated crop of each variety expressed in terms of the relative yield figures defined in Table I, and based on the observations of Swarbrick and Umpleby (1941-2), Pickford (1944-5),

Burroughs and Stanton (1946) and Stanton (1947). In Table IIa the twenty-three varieties included are those for which each mean relative yield figure is based on ten or more observations. Table IIb lists the remaining ten varieties, for each of which fewer than ten observations are available: these figures are, in consequence, less trustworthy than those in Table IIa.

TABLE I.

Relative yield figures	Corresponding terms	
0	No crop	
1	Trace crop	
2	Quarter crop	
3		Light
4	Half crop	
5		Medium
6	Three-quarters crop	
7		Heavy
8	Full crop	
9		
10	Very full crop	

TABLE IIa.

MEAN RELATIVE YIELD FIGURES, 1941-47, EACH BASED ON TEN OR MORE OBSERVATIONS.

Variety	No. of observations	Mean relative yield figure	Variety	No. of observations	Mean relative yield figure
Dabinett	27	6·4	Upright Medaille d'Or	27	2·9
Yarlington Mill	27	5·8	Dymock Red	27	2·8
Bulmer's Norman	24	5·6	Stoke Red	18	2·6
Reine des Pommes	24	4·5	Royal Wilding	13	2·3
Reinette Obry	14	4·4	Kingston Black	25	2·1
Chisel Jersey	18	3·9	Frederick	18	1·8
White Close Pippin	19	3·8	Ellis Bitter	20	1·7
Sherrington Norman	10	3·6	Woodbine	13	1·5
Tardive Forestier	24	3·6	Knotted Kernel	23	1·4
Perthyre	27	3·5	Foxwhelp	26	1·4
Broadleaf Norman	27	3·5	Silver Cup	25	1·3
Sweet Alford	27	3·0			

TABLE IIb.

MEAN RELATIVE YIELD FIGURES BASED ON FEWER THAN TEN OBSERVATIONS.

Variety	No. of observations	Mean relative yield figure	Variety	No. of observations	Mean relative yield figure
Medaille d'Or	3	5·0	Star of Devon	4	2·0
Michelin	8	4·9	London Red	5	1·6
White Jersey	6	3·5	Cap of Liberty	9	1·4
Dove	7	2·6	Red Jersey	5	1·0
Fair Maid of Devon	2	2·5	Slack-ma-Girdle	9	0·6

Years.

Table III gives the values for the mean crop of all varieties at all centres each year from 1941 to 1947. The low value for 1945 is due to the spring frost of that year.

TABLE III.

SEASONAL EFFECT ON YIELDS.

Year	1941	1942	1943	1944	1945	1946	1947
Mean relative yield figure	3·5	2·5	no record	3·3	1·6	3·0	3·5

Correlation of mean relative yield figures with crop weights.

In Table IV the mean relative yield figures from Table IIa are compared with actual crop weights for 1947 taken on ten trees of each of fourteen varieties at the Hereford and Faversham centres, and computed on an acreage basis, allowing 106 trees per acre.

TABLE IV.

CORRELATION OF ESTIMATES WITH YIELDS PER ACRE.

Variety	Mean rel. yield figure 1941-47	Actual crop weight 1947 tons/acre		Variety	Mean rel. yield figure 1941-47	Actual crop weight 1947 tons/acre	
		Hereford	Faversham			Hereford	Faversham
Dabinett	6·4	11·2	4·3	Broadleaf	3·5	0·6	11·3
Yarlington Mill	5·8	12·0	12·1	Sweet Alford	3·0	4·8	3·9
Bulmer's Norman	5·6	16·0	15·2	Kingston Black	2·1	0·2	6·3
Michelin	4·9	12·0	14·7	Ellis Bitter	1·7	1·4	5·3
Reine des Pommes	4·5	7·4	14·6	Knotted Kernel	1·4	2·4	6·3
Tardive Forestier	3·6	7·0	15·5	Foxwhelp	1·4	3·4	4·3
Perthyre	3·5	2·2	11·3	Silver Cup	1·3	1·2	5·6

Table IV shows that the order of actual yield is fairly well correlated with that of the estimates. The divergence apparent in the variety Dabinett is probably due to the fact that Dabinett produces a small tree, which prejudices its yield per acre when this variety is planted at the same spacing as the stronger growing sorts. With closer planting, it is likely that the yield per acre of Dabinett would approach that of Yarlington Mill.

DISCUSSION.

In spite of the effect of two poor cropping years (1942 and 1945) and of variations in management at the different centres, it is clear that, over a range of soil types and conditions, a group of varieties, in particular Yarlington Mill, Dabinett, Bulmer's Norman and Reine des Pommes, consistently show high-yielding properties when grown as bush trees. This indicates that in bush cider production there is no apparent reason to limit these varieties to specific localities in the way that is often characteristic of the distribution of cider varieties in standard orchards.

The high reputation of Sweet Alford is not confirmed by these trials, but it may be that the correction of magnesium deficiency, to which this variety is specially susceptible (1), would re-establish its reputation as a heavy cropper.

Many of the well-known West Country varieties of high vintage repute, such as Kingston Black, Frederick, Cap of Liberty, Knotted Kernel, Woodbine, Foxwhelp and Silver Cup have not, up to the present, yielded well in the bush cider trials. The four last-named make trees of upright habit which

take many years to come into full bearing. It is therefore too early to judge the potentialities of these varieties in the bush cider trials. The failure of Cap of Liberty to crop is probably due to its susceptibility to canker. The growth of Kingston Black has been shown by Forshaw (2) to be much influenced by locality, and this variety is apparently suited only to particular sites.

CONCLUSIONS.

From the data here submitted it will be seen that among the varieties of cider apples in the trial are some that have been shown to be suitable for bush culture over a wide range of conditions, namely : Dabinett, Bulmer's Norman, Yarlington Mill and Reine des Pommes.

It would appear that the planting distance (20 × 20 ft.) used in the trials will require amendment, as the trees at some centres (Hereford, Much Marcle, Compton Greenfield, Faversham) are now interlacing.

SUMMARY.

An account is given of the cropping of thirty-three varieties of cider apples grown as bush trees at seven centres.

The mean cropping capacity of these varieties over a period of six years (6th to 11th year from planting) has been estimated and compared with crop weights obtained at two centres in 1947.

The varieties Dabinett, Bulmer's Norman, Yarlington Mill and Reine des Pommes appear suitable for bush culture over a wide range of conditions.

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BLACK CURRANT BREEDING AT LONG ASHTON.

By G. T. SPINKS.

The breeding of new varieties of black currants at Long Ashton was first undertaken on any considerable scale in 1916, though a small number of seedlings had been raised a few years previously, and since that date a succession of families of seedlings has been produced at intervals.

In assessing the value of a variety to a fruit grower a large number of characters have to be considered, some of those desirable being vigour of growth, resistance to pests and diseases, large sized fruit, long trusses and a

fairly tough fruit skin. The question of fruit flavour is not so important as in the case of some other kinds of fruit, as there are not very wide differences between the flavours of different varieties of black currant. A sweet fruit, however, is probably more desirable than one which is very acid. It is now known that, for certain uses, the fruit should contain a high amount of ascorbic acid, but this was not known to be of importance when the breeding work was started.

In the opinion of the commercial grower probably the most important thing to be considered is the weight of fruit obtained per acre. Apart from questions of culture and manuring, the crop weight is determined by a number of separate factors, including size of individual berry, number of berries per truss or raceme, number of trusses per node, length of internode and total length of fruiting wood produced by a bush. On the whole, however, the grower considers the sum of all these factors as shown by the total crop weight, rather than the separate factors.

The breeding programme aimed primarily at the production of heavy-cropping varieties in which as many other good characters as possible are combined. In addition to various qualities mentioned above, earliness and lateness of fruit ripening were considered to be of importance.

EXPERIMENTAL.

In order to obtain seed, trusses of unopened blossoms of the variety to be used as the female parent were enclosed in paper bags, the blossoms being emasculated if a cross was to be made. A few days later the blossoms were hand-pollinated either with their own pollen or with pollen from another variety. When the fruit was set the paper bags were replaced by muslin bags until the fruit was ripe. The seed was obtained in a good condition for sowing by expressing the pulp from the berries, mixing with a small quantity of sand and enclosing in a small piece of muslin which was then squeezed under running water until all soluble matter had been removed. The residue, when dried, provided a clean mixture of seed and sand in a suitable state for sowing.

The seed was sown within a few weeks in seed-boxes in an unheated greenhouse or frame and usually germinated in about a month's time. No stratification or period of storage under cool conditions is necessary. The seedlings were transferred to small pots when large enough to handle and after more growth had been made in the following spring they were planted out in nursery rows. After one, or sometimes two, seasons of growth in the nursery they were treated like rooted cuttings and planted out in the positions in which they were to fruit. Thereafter they were treated in exactly the same way as any ordinary plantation. They bore their first crop in the second or third summer after planting.

Two families of seedlings were raised in 1913 from self-pollinated varieties. In 1916 six families were raised, two of these being ' selfs ' and four the result of crossing. At that time the classification and correct nomenclature of black currant varieties had not been completed by the East Malling Research Station and there is no satisfactory evidence that the varieties from which these seedlings originated were in fact correctly named. The names by which the parent plants were known here are, however, given in Table I.

In 1920 and 1921 eight more families were raised, of which one was the result of selfing and the remainder were crosses. The parents used were known to be true to name and included representatives of each of the four principal groups of black currant varieties.

One family of seedlings was obtained in 1929 by crossing Baldwin with an unidentified variety which resembled Boskoop.

By 1929 a number of promising seedlings had been propagated and in

TABLE I.

NUMBERS OF SEEDLINGS RAISED AND PROPAGATED.

Parents	Date	Seedlings	Propagated	Named	Under trial 1947
Black Naples selfed	1913	135	1	—	—
Ogden's Black selfed		98	1	—	—
Baldwin selfed	1916–20	151	8	—	—
Black Naples × Boskoop	1916	28	—	—	—
Ogden's Black × Baldwin		30	—	—	—
,, ,, × Black Naples		48	2	—	—
,, ,, × Boskoop		76	2	—	—
Boskoop selfed	1916–21	141	3	—	1
Baldwin × French	1920–21	180	9	—	—
,, × Seabrook		39	—	—	—
,, × Boskoop		211	4	1	—
,, × Victoria		232	11	2	1
French × Baldwin		196	2	—	1
,, selfed		124	1	—	—
Boskoop × Baldwin		163	8	—	1
,, × Seabrook		82	—	—	—
Unknown (Boskoop type) × Baldwin	1924	116	5	—	2
N.S. 124 selfed	1929	447	—	—	—
O.P. 21 selfed		272	1	—	—
O.S. 24 selfed		402	1	—	—
P.S. 24 selfed		369	3	—	3
P.S. 24 × O.S. 24		184	3	—	—
		3724	65	3	9

that year four of these were used as parents for the production of new families. A ' selfed ' family was obtained from each of the four parents and one family was also raised by crossing two of the parents.

All seedling plants were kept under observation during three cropping seasons and during that time notes were made on the various characteristics

of each plant. As the primary object of raising these seedlings was the production of good new varieties, and not the investigation of the genetics of black currants, almost all the data recorded were obtained by visual inspection and very few quantitative data were obtained by actual measurement. An attempt was made, however, to assess the grade into which each plant fell for certain characters, for instance the habit of a bush was described as erect, medium or spreading and the size of the fruit as large, medium or small. The main characters recorded were vigour of bush, habit, crop, size of berry, length of truss, season of blossom and season of fruit. In selecting plants for propagation the chief consideration was that of crop and no seedling was propagated unless it appeared to be a heavy cropper even though it might have other good qualities. Reasonably vigorous growth and fruit of good size were considered essentials in any plant to be propagated.

The number of plants selected from each family for further trial is shown in Table I. The selected seedling plants were propagated by cuttings in the usual way and in the earlier years of the investigation small quantities of these clones were grown in various plots. The first extensive and properly designed trial plot was planted out in March 1929 and included 41 clones of selected seedlings, also Boskoop and two strains of Baldwin for purposes of comparison. The whole plot was divided into three sections, each of which included a unit of each clone. The unit consisted of 24 bushes planted in line and the units were planted at random in each section of the plot. The usual observations were made on the characters of the clones and in addition the crop harvested from each unit was weighed every year. The first crop, which of course was very small, was picked in 1930 and thereafter crops increased in weight until the third, fourth or fifth year of cropping, though not regularly, owing to weather conditions. After the fourth crop, in 1933, it was decided that 29 of the seedling clones were not up to the standard required and no further records were made of their crops. The weight of fruit from the remaining 12 seedling clones and the two standard varieties was recorded for another three years, after which the plot was grubbed.

Judging from the results of this and earlier trials it was decided in 1933 that two seedling varieties were worthy of general cultivation and they were then made available for distribution under the names of *Mendip Cross* and *Cotswold Cross*. The former of these was derived from a cross between Baldwin and Boskoop and is as early in season as Boskoop, while Cotswold Cross is of the same season as Baldwin and originated in a cross between Baldwin and Victoria. Between 1935 and 1938 new small trial plots were planted with bushes of seven clones from the large trial (in addition to the two named seedling varieties), five clones from the 1924 cross between an unknown Boskoop type and Baldwin, and eight clones from the second generation seedlings raised in 1929. In 1946 it was decided to name another variety *Malvern Cross*. This is slightly later in season than Baldwin and was derived from the cross between Baldwin and Victoria. The later trials resulted in the elimination of several more clones and by 1947 only nine un-named seedling varieties remained under trial.

The three new named varieties have been included in other trials at Long Ashton, an account of which is given by Hobbis (1948) in another part of this Annual Report. All these varieties are now available as certified stocks from nurserymen and the two earlier introductions are being grown commercially in considerable quantities. Brief descriptions of these varieties are as follows :—

Mendip Cross. Ripens at the same time as Boskoop. Growth vigorous and slightly spreading: any tendency towards excessive spreading can be corrected by suitable pruning. Berries medium to large, on fairly long trusses, moderately sweet, skin moderately tough. A heavy cropper: better than Boskoop at Long Ashton.

Cotswold Cross. Same season as Baldwin. Growth vigorous and upright. Berries moderately large, on compact trusses, moderately sweet, skin thick, a heavy cropper.

Malvern Cross. Ripens a few days later than Baldwin. Growth vigorous and upright. Berries moderately large, even in size, on compact trusses of moderate length, easily detached from strig, fairly sweet, skin thick. Good cropper.

None of these varieties are as susceptible as Baldwin to the leaf spot fungus and none are noticeably liable to scorching by lime-sulphur sprays.

Particulars of the crop weights yielded by these varieties in trials at Long Ashton are given in the paper by Hobbis.

In Table I figures are given showing the number of seedlings raised in each family, the number of those initially selected for propagation and the number of seedling varieties which have been named or are still under trial.

One of the most important uses to which black currants are now put is the manufacture of syrup, which is valuable medicinally on account of the ascorbic acid it contains. Different varieties of currants contain different amounts of ascorbic acid and there is naturally a demand from the manufacturers for those varieties with a high content of this constituent. It is also an advantage to the manufacturer to have the supply of fruit spread out over a long season and it was therefore decided in 1947 to raise seedlings in which it was hoped to combine lateness in ripening with a high ascorbic acid content. The parents selected were (1) Baldwin, which is fairly late in season and has the highest ascorbic acid content of any variety in cultivation, (2) Malvern Cross, which is later in season but is low in ascorbic acid, and (3) a seedling variety known as B.V. 140, which is as late as Malvern Cross but contains more ascorbic acid. The following crosses were made:

Baldwin	×	Malvern Cross
Baldwin	×	B.V. 140
B.V. 140	×	Baldwin

A large number of seeds were obtained and many seedlings are already growing. The seedling plants will be grown and observed as in the case of previous families and the fruit of promising individuals will be analysed in order to determine the content of ascorbic acid. Any plants which are rich in this constituent and are also satisfactory in other respects will be propagated for further trial.

DISCUSSION.

Some of the data obtained from observation of the families of seedlings are set out in Table II and III. For each character under consideration an attempt was made to place a plant in one of five, or in some cases three, grades and each plant was allotted to its appropriate grade as the result of visual inspection. Thus a bush might be considered to be vigorous, moderately vigorous, medium, moderately weak or weak, in growth. The figures in the tables show the number of seedlings of each family which were placed in each grade for each character.

TABLE II.

NUMBERS OF SEEDLINGS SHOWING CERTAIN CHARACTERS OF GROWTH.

Parents	Vigour of growth					Habit of bush			Season of bloom					Length of truss				
	Vigorous	Mod. vig.	Medium	Mod. weak	Weak	Erect	Medium	Spreading	Early	Mod. early	Medium	Mod. late	Late	Long	Mod. long	Medium	Mod. short	Short
Baldwin selfed ..	—	—	3	3	16	11	8	3	14	3	3	2	—	—	1	15	4	2
Baldwin × French ..	3	14	103	14	38	59	79	32	46	30	52	20	30	2	6	67	38	55
French × Baldwin ..	6	15	97	21	51	108	70	10	46	30	62	20	29	6	7	74	33	59
Baldwin × Seabrook	—	1	25	9	4	15	16	6	15	—	11	2	10	4	6	22	5	2
Baldwin × Boskoop	1	—	54	52	101	76	78	57	87	51	44	16	7	3	43	123	29	6
Boskoop × Baldwin	39	14	84	13	11	35	67	56	56	26	48	19	12	15	44	90	4	5
Baldwin × Victoria ..	129	31	66	3	2	66	100	67	89	9	47	8	53	9	33	146	40	9
Boskoop selfed ..	—	—	2	9	19	12	13	3	1	1	16	14	6	1	2	21	2	2
Boskoop × Seabrook	5	1	58	8	7	22	45	12	2	—	31	24	26	6	13	40	6	6
French selfed.. ..	1	1	21	28	62	56	42	15	1	1	28	54	34	—	3	44	11	30

These figures indicate that in every family there is a considerable range for each character. No data were obtained from the fairly large number of

TABLE III.

Numbers of Seedlings Showing Certain Fruit Characters.

Parents	Crop					Size of Fruit					Season of Fruit				
	Heavy	Mod. Heavy	Medium	Mod. light	Light	Large	Mod. large	Medium	Mod. small	Small	Early	Mod. early	Medium	Mod. late	Late
Baldwin selfed	—	15	6	—	2	—	—	12	6	4	—	—	13	4	5
Baldwin × French ..	15	68	68	19	1	1	17	109	38	3	6	9	74	46	38
French × Baldwin ..	9	67	98	5	4	2	14	104	46	14	2	10	46	47	71
Baldwin × Seabrook ..	1	5	9	20	2	—	—	26	12	1	2	4	22	6	4
Baldwin × Boskoop ..	16	67	103	16	7	6	40	110	47	8	14	44	121	23	10
Boskoop × Baldwin ..	15	33	52	56	4	10	45	75	29	2	6	33	78	30	18
Baldwin × Victoria ..	20	72	81	19	14	16	39	160	17	1	11	11	67	50	92
Boskoop selfed	—	1	21	3	2	1	3	15	4	4	12	4	10	2	1
Boskoop × Seabrook ..	2	15	34	7	11	6	19	42	2	—	10	—	37	19	8
French selfed	—	6	64	5	14	1	2	50	22	13	2	17	64	6	3

seedlings from Baldwin selfed in 1916, but the small number in this family raised at a later date, the small family of Boskoop 'selfs' and the larger one of French 'selfs' all show a general tendency to resemble the parent though there is quite a large amount of variation.

The families raised from crosses also exhibit this gradation in the case of all the characters studied. When two parents differ distinctly in respect of a character a few of the seedlings resemble each parent but the majority occupy some intermediate position. When, however, both parents are in the same extreme grade a larger proportion of the progeny occur in that grade and a much smaller number in the opposite extreme grade. For instance, a fairly large percentage of the seedlings from the crosses between Baldwin and French bore short trusses of fruit but very few bore long trusses.

There appear to be no cases of dominance or definite segregation of any of the characters considered, except that of leaf shape, which is not included in Table II and III. The family of French 'selfs' contained a number of plants with leaves differing in shape from those of any cultivated variety. Tydeman (1930) has already recorded the occurrence of these abnormal leaf types among 'selfs' of French and Seabrook and has discussed the genetics of these characters. Families raised here from crosses between French and Seabrook and other varieties such as Baldwin and Boskoop have not included any plants with abnormal types of leaves as the factors involved are recessive and are apparently not present in the other varieties.

The data obtained from Long Ashton families very largely confirm the conclusion of Tydeman (1938) that the crossing of varieties now in cultivation may result in a hitherto unknown combination of good characters in one plant but will not produce any improvement in any one character. It is thought, for example, that no amount of intercrossing of existing cultivated varieties would result in the production of a seedling bearing longer trusses than those now carried by some of the common varieties. There appears, however, to be at least one exception to the above conclusion. Extension of the season of ripening of the fruit is a desirable aim and it is notable that the cross between Baldwin and Boskoop has produced two seedlings which ripen their fruit distinctly earlier than Boskoop, though further trial is necessary before deciding whether either of these is sufficiently good in other respects to be of commercial value. Again, two seedlings from the cross between Baldwin and Victoria are distinctly later in season than Baldwin. One of these has already been named Malvern Cross and the other is still under trial.

The figures in Table I show that of 3724 seedlings 65 were considered worthy of propagation and that three of these have been named and nine are being given a further trial. It may be noticed that the largest families, which consisted of second generation plants from selected seedlings, supplied a very small number of seedlings thought to be worth propagating, but it is doubtful whether they were really as inferior to the other families as the figures suggest. In the first place, these large families were grown under rather poor cultural conditions and may not have been able to show their qualities to the full: secondly, it is possible that the standard required for selection may have been raised unconsciously since the earlier selections were made.

The results obtained from the comparatively small families under review suggest that it is unlikely that any very good new varieties can be obtained by selfing any of the existing cultivated varieties. The progeny of crosses between these varieties, however, has included seedlings of value on account of the occurrence of a combination of some of the good qualities of both parents. It therefore seems possible, as Tydeman has suggested, that the raising of larger families from crosses between certain parents would result in the appearance of a few seedlings in which still larger numbers of desirable characters are found in combination. Consideration of the seedlings already produced

suggests that suitable crosses for this purpose are Baldwin × Boskoop and Baldwin × Victoria. Large families of 'selfs' from some of the best F_1 plants already selected might also include seedlings combining more good characters. As noted above, several fairly large families of F_2 plants did not include many individuals of value but it is possible that the use of other F_1 varieties such as Mendip Cross and Cotswold Cross, which are superior to those previously used, would result in a better F_2 generation.

SUMMARY.

As the result of crossing or 'selfing', 22 families of black currant seedlings, including a total of 3,700 individuals, have been raised. The parents consisted of some of the best cultivated varieties.

Fruiting trials have been carried out with plants propagated from selected seedlings. Three new varieties have been named Mendip Cross, Cotswold Cross and Malvern Cross, respectively, while nine other varieties are still under trial.

The data obtained from observation of the various families suggest that no outstanding plants are likely to be produced by 'selfing' well-known cultivated varieties, but that large families obtained by crossing such varieties might include seedlings in which a larger number of desirable characters are combined. It seems possible that such combinations of qualities might also be found in some of the plants in the second generation raised from these crosses.

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THE MANAGEMENT AND CROPPING OF BLACK-CURRANT PLANTATIONS AT LONG ASHTON AND IN THE SOUTH-WEST.

By E. W. HOBBIS.

The climate and many of the soils of S.W. England are well suited to the profitable growing of blackcurrants, and the Long Ashton Research Station has had many years' experience with this crop. Previous articles by members of the staff have dealt with the control of pests and diseases (4, 5, 7), new varieties (6), and utilization of the fruit (2): the present paper covers systems of planting, cultivation, manuring, pruning and yields. Cropping data are given for a number of varieties grown in recent years at the Research Station and at two other centres in the South-West.

Systems of Planting.

The choice of methods of spacing blackcurrants will be influenced by the following considerations:

(1) Heavy yields necessitate a high production per acre of bearing wood.

(2) Close planting of bushes enhances their smothering effect on annual weeds, thus helping to obviate hand labour.

(3) Mechanical cultivation must be employed to the greatest possible extent.

(4) Speed and efficiency of spraying are essential.

While points (1) and (2) call for close planting, (3) and (4) demand a system of spacing that will enable cultivating and spraying machinery to traverse the rows in at least one direction without damaging the bushes. A spacing which would permit tractor working in both directions would drastically reduce the number of bushes so that returns per acre would be restricted at least in the first 5 years after planting. The compromise necessary is therefore the adoption of a ' hedge ' system, with the plants not more than 4 ft. apart in the rows. In deciding the width of the alleyways between the rows, the most difficult requirement to satisfy is accessibility for spraying. A small spraying outfit is inefficient and slow ; the tractor-trailer type is at the moment the most labour- and time-saving, the limiting factor being the dimensions of the tractor, which is generally a wheeled type about $5\frac{1}{2}$ ft. overall width. As the sides of blackcurrant bushes slant widely outwards, wheeled tractors tend to ' ride down ' the branches and therefore need a clearance of approximately 2 ft. from the bases of the bushes on both sides. Adding to this the thickness of the base of the bush, it is necessary to consider a planting distance of approximately 10 ft. between the rows as desirable.

The alternative is to provide cross roads every 150 ft., enabling spraying to be done from the alleyways with spraymen using 90 ft. lengths of hose. This hose length will be found the maximum which can be handled without undue fatigue on a heavy soil.

Roadways for this particular purpose could be left at stated intervals when a plantation is first planted. Alternatively such roadways can easily be cut at some later date indicated by the time when access along the rows becomes difficult.

The large-scale grower will undoubtedly be attracted by a wide row spacing such as 10 ft. but the smaller grower with smaller cultivating equipment can well afford to plant at an 8 ft. spacing, provided always that cross-roads are left at convenient intervals to facilitate spraying operations.

Whatever planting distance is adopted it is worth while to line out the rows accurately in both directions at planting time. In this way the ground can be worked thoroughly and cheaply during the first year by cultivations in both directions and, where wheeled tractors are used, these can ' straddle ' the rows during the first season until such time as new shoot growth is too high to pass under the tractor without damage.

Cultivation.

The profitable life of a blackcurrant plantation is generally accepted to be about 10 cropping years, although instances of a longer profitable life are known. The bushes fruit most heavily on young wood and the management of a plantation should be concentrated on producing as much vigorous young wood annually as possible.

Cultural management to this end becomes more difficult as a plantation ages. Unless it is maintained at a high level the annual production of young wood may be lowered, pest and diseases may take increasing toll and soil cultivations become a problem as the bushes extend in width.

Weed control, however, is a problem confined largely to the early years

of a plantation. Provided the bushes grow vigorously, annual weed has little chance of establishing itself beneath them and as they age and spread, so a greater area around each bush keeps free of weed. Perennial weeds such as couch grass, convolvulus and red knot grass, however, are extremely difficult to eradicate once they become established and if unchecked they can ruin a plantation very quickly.

Manuring.

It has been established that blackcurrants respond to a high level of manuring (8). They need an ample supply of soil moisture and of plant foods in the early months of the year when new shoot growth is being made and whilst a crop is being ripened. Annual dressings of F.Y.M. or well rotted compost plus an NPK fertilizer, with the N dressing at 4—6 cwts. per acre, have been the routine practice at Long Ashton for some years. The variety Baldwin generally needs a higher N dressing than other varieties since it tends to make little new wood in seasons of heavy cropping.

The general practice has been to apply the bulky manures during frosty weather, placing the dressing close to the bushes and not down the alleyways. Very shallow ploughing has then followed and the fertilizer dressing has been given during Feb.—March.

Planting and Pruning.

Two-year-old bushes give best results at Long Ashton. These are planted an inch or two deeper than they grew in the nursery and the young shoots cut down to within one or two buds of ground level. This ensures new growth from the base and so establishes the bushes on a 'stool' i.e. with a shoot system originating at ground level.

Between 4 and 7 shoots per bush can be expected to grow during the first year and these are allowed to fruit in the following season. Weak shoots are cut down a second time before allowing them to fruit.

After the first fruiting the practice at Long Ashton is to cut out all the shoots that have fruited, leaving new wood only to carry the second crop. This encourages the development of ample basal growth, and the pruning in subsequent years is then much lighter. No hard and fast rule can be laid down but each bush is treated on its merits, with the general ruling that a minimum of strong new wood is cut from the bushes consistent with maintaining their vigour. Older wood with little extension growth is cut close to the base of the bush or is shortened to a strong lateral shoot. Low outward-growing branches are shortened to an upright-growing lateral or cut out completely.

This method of pruning seems satisfactory for about six years from planting, after which hard basal cutting tends to produce an over-abundance of new shoots from the base, many of which, being densely shaded, often fail to grow more than a foot or so. This overcrowding of the base of the bushes can be avoided by a judicious thinning out of older wood. Alternatively, as the bushes become larger it may be necessary to shorten more and more to strong lateral growths, thinning the bushes slightly and encouraging further new shoots from the lower but not basal parts of the bushes. This thinning will tend to concentrate fruiting on the upper parts of the bushes but this has the advantage that as a plantation becomes fully grown the fruit is better exposed to light. It does however make spraying more difficult.

Varieties.

Some varieties, e.g. Baldwin, yield well over most of the country; others, such as Boskoop Giant, are in local favour; and at least one variety, Edina, is unsatisfactory as a source of juice since it has a low vitamin C content. From the processors' point of view, the varieties Mendip Cross, Baldwin and Westwick Choice are of particular merit, as their vitamin C content is high and these fruits help the manufacturer in maintaining a required vitamin standard.

Under the Sale of Blackcurrant Bushes Order 1946, the sale of bushes is prohibited except under licence. Certificates are issued annually to growers whose nursery stocks or bushes from which cuttings are taken comply with certain high standards relating to purity of stock and freedom from reversion at the time of inspection. The register of growers holding certificates now lists some 26 classified varieties falling within the four types, French, Boskoop Giant, Goliath and Baldwin, and 19 varieties which are unclassified.

The grower in the S.W. however, can rely mainly on a selection from the varieties Boskoop Giant, Mendip Cross, Seabrook's Black, Cotswold Cross, Baldwin and Westwick Choice.

If a large acreage is grown it is advisable to grow two or more varieties in order to spread the picking period over as long a period as possible so that the whole crop can be picked whilst in the best condition. The harvesting period, however, even where both early and late picking varieties are grown may be compressed into about three weeks and if inclement weather sets in during this period the crop condition may deteriorate rapidly, due to over-ripeness and consequent splitting of the berries.

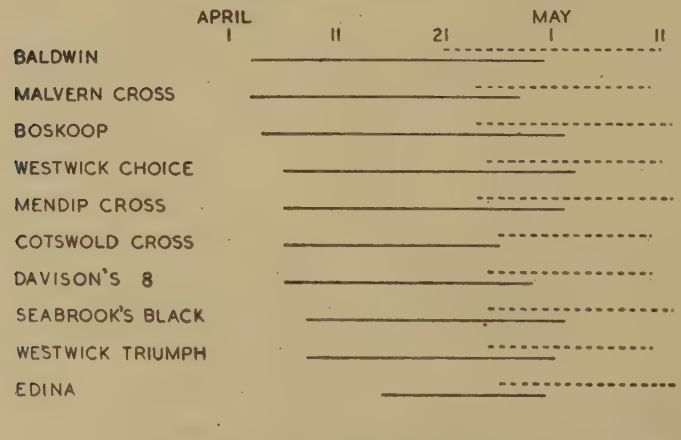
All picking at the Research Station is done on a piece-work payment and it is reasonable to expect 20 pickers to clear one ton of fruit per day.

The flowering time of all varieties is not the same and the growing of several sorts may therefore reduce to some extent the risk of damage from frost.

Blossoming Periods.

At Long Ashton the blossoming periods of some 10 varieties have been noted over the past two seasons and these are set out in the diagram below.

FLOWERING PERIODS OF 10 VARIETIES OF BLACKCURRANTS
AT LONG ASHTON RESEARCH STATION 1946 & 1947



Crop Records at Long Ashton.

The plots at the Research Station were not laid out for the purpose of obtaining records of yield but were established chiefly for investigations of nutrition and pest and disease control. Sufficient data exist, however, to give a picture of the cropping performance of some ten varieties receiving closely allied cultural treatment under similar environmental conditions over periods ranging up to five consecutive cropping seasons.

Table I sets out the plot data concerning nine varieties planted at 7 ft. 6 in. × 7 ft. 6 in., i.e. 774 per acre. The weight of crop per bush and per acre

TABLE I.

RECORDS FROM LONG ASHTON PLOT PLANTED 7FT. 6 IN. × 7 FT. 6 IN. CROP PER BUSH IN LB. (UPPER FIGURE). CROP PER ACRE IN TONS (LOWER FIGURE).

Variety	Spacing	Planted	1943	1944	1945	1946	1947	Mean in ft. (1947)	
								Ht.	Spread
Boskoop	7′ 6″ × 7′ 6″	1940–41	3·07 1·06	4·91 1·69	3·66 1·26	8·82 3·05	10·50 3·63	6	8
Baldwin	do.	do.	4·61 1·59	4·48 1·55	6·22 2·15	9·99 3·45	18·50 6·39	4·5–5	4·5–5
Seabrook	do.	do.	2·16 0·75	4·66 1·61	5·75 1·19	10·50 3·66	10·70 3·69	6	8
W. Choice	do.	do.	5·68 1·96	9·63 3·33	4·50 1·55	9·88 3·41	20·00 6·91	5	6
W. Triumph	do.	do.	2·80 0·97	5·39 1·86	3·84 1·33	8·45 2·92	12·20 4·22	5·5	6·5
Davison's 8	do.	do.	5·19 1·79	4·23 1·46	0·95 0·33	8·26 2·85	11·10 3·83	5	5·5
Edina	do.	do.	3·00 1·04	2·63 0·91	3·23 1·11	10·88 3·48	9·50 3·28	5·5	6·5
Mendip X	do.	1942–43		2·56 0·88	2·69 0·93	10·87 3·76	12·20 4·22	4·5	6·5
Cotswold X	do.	do.		3·87 1·34	2·66 0·92	8·17 2·63	11·00 3·80	5	6

is given and also the mean height and spread of the bushes in 1947. Table II summarises the yields set out in Table I and gives the average crop per bush per year over 5 cropping seasons. The varieties are tabled in order of yield.

In 1943 an experiment on the use of organic manures was laid down at the Research Station. (1) The varieties Mendip Cross and Cotswold Cross were planted at 8 ft. × 4 ft., i.e. 1,361 per acre. A third variety, Malvern Cross, was also planted but not included in the manurial experiments.

Table III sets out the growth and yield of bushes of the three varieties which have received manurial treatments comparable to those set out in Tables I and II.

Table IV shows the growth and yield obtained from 2 acres of the varieties Baldwin and Seabrook growing at 10 ft. × 3 ft. 4 in. These bushes were originally planted out at 10 ft. × 10 ft. in 1941 and were intercropped intensively with vegetables from 1941—1944 inclusive. By that time the bushes

were suffering from the intercropping so this was discontinued and the currant rows were gapped up at 3 ft. 4 in. in one direction. This plot has never completely recovered from the vegetable intercropping and the growth and yield figures have been reduced owing to this adverse factor in management.

TABLE II.

SUMMARISED RECORDS FROM TABLE I. AVERAGE CROP PER BUSH AND TONS PER ACRE PER YEAR, OVER 5 CROPPING SEASONS (1943–47), IN ORDER OF YIELD :

Variety	Crop per bush	Tons per acre
W. Choice	9·94	3·43
Baldwin	8·76	3·03
Mendip X	7·08	2·45
Seabrook	6·77	2·34
W. Triumph	6·54	2·26
Cotswold X	6·42	2·22
Boskoop	6·19	2·14
Davison's 8	5·95	2·06
Edina	5·69	1·97

TABLE III.

RECORDS FROM LONG ASHTON PLOT PLANTED 8 FT. × 4 FT. CROP PER BUSH IN LB. (UPPER FIGURE) : CROP PER ACRE IN TONS (LOWER FIGURE).

Variety	Spacing	Planted	1945	1946	1947	Height	Spread
Mendip X	8′ × 4′	1943–44	0·32 0·19	3·47 2·11	6·38 3·88	4–4·5′	5·5–6′
Cotswold X	do.	do.	0·21 0·13	4·23 2·57	6·09 3·70	4·5′	5·5′
Malvern X	do.	do.	0·03	2·99 1·82	5·60 3·40	4′	4·5–5′

Somerset Centres.

Yield data have also been collected since 1944 from plantings in two areas in Somerset. At each centre bushes of four varieties were set out in the winter of 1942–43 at the close spacing of 7 ft. × 3 ft., i.e. 2,074 per acre. Approximately 4 acres and 2 acres were planted at Centres 1 and 2 respectively. At both centres blackcurrants had been grown for some years and the respective growers had a good knowledge of the field requirements of the crop.

At No. 1 centre manuring was based on annual dressings of poultry manure —straw compost plus potash fertilizer whilst at No. 2 centre F.Y.M. plus NPK was used. Tables V and VI set out the yields per bush and per acre. In the 2 plots at Centre No. 1 picking weights from the varieties Boskoop and Seabrook and of Baldwin and Westwick Choice have always been bulked so these are shown as Early and Late.

Table VII although showing the crop weights from each of the four varieties at Centre No. 2 also uses the groupings Early and Late for a comparison with Tables V and VI.

At No. 2 centre a further 2 acre plot was put down in 1943–44 and Table VIII sets out the crop weights for the past three cropping years.

TABLE IV.

RECORDS FROM LONG ASHTON PLOT PLANTED 10 FT. × 3 FT. 4 INS. CROP PER BUSH IN LB. (UPPER FIGURE): CROP PER ACRE IN TONS (LOWER FIGURE).

Variety	Spacing	Planted	1944	1945	1946	1947	Height	Spread
Baldwin	10′ × 3′ 4″	1941–42	1·04 0·61	0·53 0·31	1·94 1·13	4·84 2·82	3–3·5′	2·5–3′
Seabrook	do.	do.	1·47 0·86	0·68 0·40	1·81 1·06	4·24 2·47	3·5–4′	5′

N.B. 1945 crops were spoiled by May frosts.

TABLE V.

RECORDS FROM SOMERSET CENTRE NO. 1, PLOT A. CROP PER BUSH IN LB. (UPPER FIGURE): CROP PER ACRE IN TONS (LOWER FIGURE).

Variety	Spacing	Planted	1944	1945	1946	1947	Average
Early	7′ × 3′	1942–43	0·88 0·81	0·94 0·87	not given separately	2·84 2·63	
Late	do.	do.	1·21 1·12	0·75 0·69		3·06 2·83	
Total			0·80 0·96	0·84 0·78	4·32 4·00	2·95 2·73	2·29 2·12

TABLE VI.

RECORDS FROM SOMERSET CENTRE NO. 1, PLOT B. CROP PER BUSH IN LB. (UPPER FIGURE): CROP PER ACRE IN TONS (LOWER FIGURE).

Variety	Spacing	Planted	1944	1945	1946	1947	Average
Early*	7′ × 3′	1942–43	0·59 0·55	1·77 1·84	not given separately	3·80 3·52	
Late ±	do.	do.	1·01 0·94	0·83 0·77		4·87 4·51	
Total			0·80 0·74	0·95 0·88	4·65 4·31	4·35 4·01	2·68 2·49

* Early = Boskoop + Seabrook
± Late = Baldwin + W. Choice
1945 Frost Year

TABLE VII.

RECORDS FROM SOMERSET CENTRE No. 2, PLOT A. CROP PER BUSH IN LB. (UPPER FIGURE): CROP PER ACRE IN TONS (LOWER FIGURE).

Variety	Spacing	Planted	1944	1945	1946	1947	Average
Boskoop	7′ × 3′	1942–43	0·88 0·82	0·83 0·77	5·01 4·64	3·53 3·27	2·56 2·37
Seabrook	do.	do.	1·06 0·98	1·89 1·75	7·03 6·51	3·28 3·04	3·31 3·07
Early*	do.	do.	0·97 0·90	1·36 1·26	6·02 5·57	3·40 3·15	2·94 2·72
Baldwin	do.	do.	1·14 1·06	1·24 1·15	4·22 3·91	4·14 3·83	2·69 2·49
W. Choice	do.	do.	1·65 1·53	1·80 1·67	3·69 3·42	5·18 4·80	3·08 2·85
Late ±	do.	do.	1·40 1·29	1·52 1·41	3·95 3·66	4·66 4·31	2·88 2·67
Total			1·18 1·09	1·45 1·34	4·99 4·62	4·03 3·73	2·91 2·69

TABLE VIII.

RECORDS FROM SOMERSET CENTRE No. 2, PLOT B. CROP PER BUSH IN LB. (UPPER FIGURE): CROP PER ACRE IN TONS (LOWER FIGURE).

Variety	Spacing	Planted	1945	1946	1947	Average
Boskoop	7′ × 3′	1943–44	0·07 0·06	2·43 2·25	3·61 3·34	2·04 1·89
Seabrook	do.	do.	0·23 0·22	5·27 4·88	3·53 3·27	3·01 2·79
Early*	do.	do.	0·15 0·14	3·84 3·55	3·52 3·26	2·50 2·31
Baldwin	do.	do.	0·40 0·37	6·08 5·63	5·59 5·18	4·02 3·72
W. Choice	do.	do.	0·12 0·11	3·12 2·89	4·37 4·05	2·54 2·35
Late ±	do.	do.	0·25 0·23	4·60 4·26	4·97 4·60	3·27 3·03
Total			0·21 0·19	4·22 3·91	4·27 3·95	2·90 2·68

* Early = Boskoop + Seabrook
± Late = Baldwin + W. Choice
1945 = Frost Year

The above crop records show that at Long Ashton both Westwick Choice and Baldwin have cropped very heavily over a period of 5 years. Mendip Cross may prove to be as heavy a cropper as both Westwick Choice and Baldwin as this variety growing on another plot and spaced at 8 ft. × 4 ft. reached a similar rate of cropping to Westwick Choice and Baldwin in the

third season. Cotswold Cross, another Long Ashton raised variety, also set out at 8 ft. × 4 ft. has approached very close to Mendip Cross over three years of cropping, producing 3·70 tons per acre as against 3·88 tons per acre from Mendip Cross in the third cropping year.

Whether or not similar results from these varieties will be maintained in future years remains to be seen. The first one or two crops are rarely heavy and the bushes do not settle down to a heavy cropping capacity until the third season after planting.

From the above records it will be seen that the varieties Westwick Choice, Baldwin and Seabrook's Black have produced heavy crops at each centre.

SUMMARY.

The planting system adopted at Long Ashton has been both square and 'hedgerow' but the latter method has proved more convenient for cultural and spraying operations. (*See Fig.* 3.)

At the two Somerset centres an unusually close 'hedgerow' planting has been adopted without undue difficulties in cultivations and spraying during the early years. At Centre No. 1, varieties Boskoop and Seabrook planted at 7 ft. × 3 ft. have cropped heavily over a period of 10 years and the land is still reasonably free of weed.

The figures relating to bush spread at Long Ashton show how rapidly the bushes can fill up the inter-row space. Close planting of the rows necessitates the 'cutting up' of bushes at some later date in order to allow of passage of implements, sprayers and pickers. Hard cutting up to allow of this has been shown to be possible on other plantations without reduction in crop on bushes planted 7 ft. × 3 ft., e.g. at Centre No. 1 on bushes cropped for 10 years.

At Long Ashton the 8 ft. × 4 ft. plant is proving very manageable so far and seems a very good spacing for horse or small power-tool cultivation. The wider plant, allowing 10 ft. between the rows is very accessible by wheeled tractor (Ferguson) six years after planting, provided a little cutting up of outside branches is practised.

The records so far obtained deal with not more than the first five crops in the life of the plantation. Although only four varieties have been grown at the Somerset centres the records of these coupled with those of Long Ashton indicate that Baldwin and Westwick Choice are heavy cropping varieties at all three places. Long Ashton experience places Mendip Cross as being the heaviest cropping early-ripening variety and where it has been grown elsewhere in the S.W. its heavy cropping qualities have been maintained. Cotswold Cross promises well at Long Ashton, as also does Malvern Cross, a late-ripening variety but further experience of these newer varieties is needed before assessing their value.

That varieties crop differently in different parts of the country is well known but a high standard of growing is essential to heavy cropping even of the best varieties. Overall, however, is the necessity of planting material of really high standard and of maintaining it as free as possible from pests and diseases. The grower must keep a keen eye open for reversion in the plantation and follow its appearance with immediate grubbing even of occasional bushes if a heavy cropping plantation is to be maintained. Annual winter washing together with control of Big Bud mite by applications of lime sulphur in spring are equally important in the maintenance of healthy long-lived plantations.

ACKNOWLEDGMENTS.

Thanks are due to Mr. E. Catlow for keeping records of crop weights at Long Ashton, to Mr. G. Clothier for observations and records on flowering dates and to Messrs. H. W. Carter & Co. Ltd., for furnishing crop weights from the two outside Centres.

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A MANURIAL EXPERIMENT ON BLACKCURRANTS. PROGRESS REPORT II.

By C. BOULD and E. CATLOW.

The object and design of this experiment was described in a previous report (1). The present report deals with growth, yield of fruit and nitrogen status of the leaves for the season 1947. For the first time since the experiment was laid down treatments had a significant effect on yield of fruit.

The quantities of manures applied in 1947 in addition to the overall dressing of KCl at 2 cwts. p.a. are given in Table I.

TABLE I.

Quantities of Manures Applied in 1947. Rates on an Equal Organic Matter Basis to 10 Tons Per Acre of F.Y.M. Fresh Weight.

Manure	Mendip Cross		Cotswold Cross	
	Fresh Wt. Tons per acre	Total N lb. per acre	Fresh Wt. Tons per acre	Total N lb. per acre
Stable manure	10	106	10	106
Drained sludge	8·97	190	8·97	190
Straw-sludge compost	10·69	161	—	—
Straw nitro-chalk compost	11·57	100	—	—
Refuse-sludge compost	—	—	13·08	200
Meat and bone meal	—	—	0·58	104
Nitro-chalk	0·30	104	—	—
Superphosphate	0·35	—	—	—

Fig. 1. A well-grown six-year-old blackcurrant bush, variety Baldwin.

Fig. 2. Useless type of blackcurrant bush on a 'leg'.

Fig. 3. Mendip Cross five years after planting at 8 ft. 4 ft.

Fig. 4. Boskoop Giant after eight crops: planted 7 ft. × 3 ft.

RESULTS, 1947.

Experiment I. Var. Mendip Cross.

Vigour. The plants were scored for vigour and foliage colour on 16/6/47. The results are given in Table II.

TABLE II.

EFFECT OF TREATMENTS ON VIGOUR AND FOLIAGE COLOUR OF BLACK CURRANTS VAR. MENDIP CROSS 1947.

Blocks	1 Stable Manure	2 Drained Sludge	3 Straw-sludge Compost	4 Straw-Nitro-chalk Compost	5 N.P. Nitro-chalk	6 Nil	Total
1	3½ S.P.	4 G	3½ G	4 S.P.	4½ G	3 P.	22½
2	3½ M.G.	4 G	3 S.P.	3 P	4½ D.G.	3 P	21
3	3½ S.P.	4 G	3½ S.P.	3½ S.P.	4½ D.G.	2 V.P.	21
4	3½ S.P.	4½ D.G.	3 G	2½ P	4½ G	2½ V.P.	20½
5	4 S.P.	4½ G	3½ S.P.	3 M.G.	5 D.G.	2½ P	22½
Total	18	21	16½	16	22	13	

Maximum points per plot = 5.

Leaf colour D.G. = dark green; G = green; M.G. = medium green; P. = pale green; V.P. = very pale green with tints.

Order of vigour; N.P. and drained sludge > Stable manure > composts > nil.

Foliage; dark green on N.P. and drained sludge plots. Low nitrogen symptoms on potash only and compost plots.

Yield of Fruit.

The fruit was picked on the 12-15/7/47. There was no appreciable difference in the state of ripeness due to treatments. Berries were somewhat larger from bushes receiving treatments 2 and 5 than from bushes receiving other treatments. Smallest berries were from treatment 6. The results for yield of fruit are given in Table III.

TABLE III.

EFFECT OF TREATMENTS ON YIELD OF FRUIT, BLACK CURRANT VAR. MENDIP CROSS.

Mean Weight	1 Stable manure	2 Drained Sludge	3 Straw-sludge Compost	4 Straw-Nitro-chalk Compost	5 N.P. Nitro-chalk	6 Nil	S.E.	Sig. Diff. 1% P
Lb. per bush	5·58	6·05	5·65	4·98	6·38	4·70	0·241	0·971
Tons per acre	3·39	3·68	3·43	3·03	3·88	2·86		
Order	(4)	(2)	(3)	(5)	(1)	(6)		

The effect of treatments on yield of fruit was significant at the 1% level of P. At 1% level of P treatments 2 and 5 > treatments 4 and 6.

At 5% level of P treatments 1, 2, 3, 5 > 6 ; and treatments 2 and 5 > 4.

Pruning Weights.

Pruning consisted of the removal of lowlying and straggling wood and a few cuts to the base of the stool. Removal of current wood was reduced to a minimum. The results are given in Table IV.

TABLE IV.

PRUNING WEIGHTS IN LB. MEAN WEIGHT PER BUSH : VAR. MENDIP CROSS.

1 Stable Manure	2 Drained Sludge	3 Straw-sludge Compost	4 Straw Nitro-chalk Compost	5 N.P. Nitro-chalk	6 Nil	S.E.
1·96	2·38	1·99	1·63	2·37	1·74	0·1185
(4)	(1)	(3)	(6)	(2)	(5)	

The effect of treatments on pruning weights was significant at the 1% level of P.

At 1% level of P treatments 2, 5 > 4, 6.
At 5% „ „ „ 2, 5 > 1, 3, 4 and 6.

Leaf Analysis.

Mature leaf samples were taken from current growth on 20/6/47 and analysed for total nitrogen. The results are given in Table V.

TABLE V.

EFFECT OF MANURIAL TREATMENTS ON THE NITROGEN CONTENT OF BLACK CURRANT LEAVES VAR. MENDIP CROSS. NITROGEN AS A PERCENTAGE OF DRY MATTER (MEAN OF 5 PLOTS). LEAVES FROM CURRENT GROWTH 20/6/47.

	1 Stable Manure	2 Drained Sludge	3 Straw-sludge Compost	4 Straw-Nitro chalk Compost	5 N.P. Nitro-chalk	6 Nil	S.E.	Sig. diff. at 1% level of P.
Total N.	2·574	2·793	2·739	2·653	2·926	2·523	0·0304	0·1223
Order	(5)	(2)	(3)	(4)	(1)	(6)		

Differences due to treatment were significant at 1% level of P.

At 1% level of P treatment 5 > 1, 2, 3, 4, 6 ; 2 > 1, 4, 6 ; 3 > 1, 6; 4 > 6.

Experiment II. Var. Cotswold Cross.

Vigour. The bushes were scored for vigour and leaf colour on 17/6/47. The results are given in Table VI.

TABLE VI.

EFFECT OF TREATMENTS ON VIGOUR AND FOLIAGE COLOUR OF BLACK CURRANT VAR. COTSWOLD CROSS.

Blocks	1 Stable Manure	2 Drained Sludge	3 Town Refuse Compost	4 Meat and Bone Meal	5 N.P. Nitro-chalk	6 Nil	Total
1	3 S.P.	4½ G	3½ P	4½ D.G.	4½ D.G.	3½ V.P.	23½
2	4½ G	4 D.G.	3½ S.P.	5 D.G.	5 D.G.	3 P	25
3	3½ G	4 D.G.	3 P	4 D.G.	4½ D.G.	2½ P	21½
4	3½ G	4 G	3½ S.P.	4½ D.G.	4½ D.G.	2 P	22
Total	14½	16½	13½	18	18½	11	
Order	(4)	(3)	(5)	(2)	(1)	(6)	

The vigour markings and foliage colour categories were the same as for Mendip Cross.

Order of vigour: N.P. > Meat and bone meal > drained sludge > stable manure > town refuse compost > nil.

Foliage colour: Plants receiving N.P. and meat and bone meal had dark green foliage. Plants receiving drained sludge were not quite so green but were darker than leaves on plants receiving stable manure. Leaves on bushes receiving town refuse compost and nil showed signs of nitrogen deficiency.

Yield of Fruit.

The fruit was picked on 17/7/47. Manurial treatments had no appreciable effect on state of ripeness or size of berry. Berries from nil plots were slightly riper and smaller than berries from bushes receiving other treatments. The crop weights are given in Table VII.

TABLE VII.

EFFECT OF TREATMENTS ON YIELD OF FRUIT. BLACK CURRANT VAR. COTSWOLD CROSS.

Mean Weight	1 Stable Manure	2 Drained Sludge	3 Town Refuse Compost	4 Meat and Bone Meal	5 N.P. Nitro-chalk	6 Nil	S.E.	Sig. diff. 1% P.
Lb. per bush	4·95	6·05	5·55	6·10	6·09	3·88	0·389	1·625
Tons per acre.	3·01	3·68	3·37	3·71	3·70	2·36		
Order	(5)	(3)	(4)	(1)	(2)	(6)		

Treatment effects were significant at the 1% level of P.
At 1% level of P treatments 2, 4, 5 > 6.
At 5% „ „ „ 2, 3, 4, 5 > 6.

Pruning Weights.

Pruning consisted of the removal of old wood and one or two cuts to the base of the stool. A higher percentage of new wood was unavoidably removed from bushes receiving treatments 2, 4 and 5 than from 1, 3 and 6.

The results are given in Table VIII.

TABLE VIII.

PRUNING WEIGHTS IN LB. MEAN WEIGHT PER BUSH VAR. COTSWOLD CROSS

1 Stable Manure	2 Drained Sludge	3 Town Refuse Compost	4 Meat and Bone Meal	5 N.P. Nitro-chalk	6 Nil	S.E.	Sig. diff. 1% P.
2·14	2·92	2·59	3·13	3·11	1·67	0·1851	0·771
(5)	(3)	(4)	(1)	(2)	(6)		

Treatment effects were significant at the 1% level of P.

At the 1% level of P treatments 2, 3, 4 and 5 > 6 ; 2, 4 and 5 > 1, 6.

Leaf Analysis.

Mature leaf samples were taken from current growth on 19/6/47 and analysed for total nitrogen. The results are given in Table IX.

TABLE IX.

EFFECT OF MANURIAL TREATMENTS ON THE NITROGEN CONTENT OF BLACK CURRANT LEAVES VAR. COTSWOLD CROSS. NITROGEN CONTENT AS A PERCENTAGE OF DRY MATTER. (MEAN OF 4 PLOTS). LEAVES FROM CURRENT GROWTH 19/6/47).

	1 Stable Manure	2 Drained Sludge	3 Town Refuse Compost	4 Meat and Bone Meal	5 N.P. Nitro-chalk	6 Nil	S.E.	Sig. diff. at 1% level of P.
Total N	2·695	2·847	2·737	2·954	3·056	2·523	0·0482	0·2009
Order	(5)	(3)	(4)	(2)	(1)	(6)		

Differences due to treatment were significant at 1% level of P.

At 1% level of P treatment 5 > 1, 2, 3, 6 ; 4 > 1, 3, 6 ; 2, 3 > 6.

Relationship Between Treatments, Leaf Nitrogen Content and Yield of Fruit.

The results for 1947 confirm those of the previous year, namely, that stable manure and composts when applied on an equal organic matter basis to 10 tons per acre of fresh stable manure do not liberate sufficient available nitrogen to maintain an adequate nitrogen status in the plant. Even sewage sludge, which contained almost twice the amount of total nitrogen as supplied by the nitro-chalk, did not liberate sufficient available nitrogen. On a unit nitrogen basis its nitrogen availability was only about one third that of nitro-chalk. There was no significant difference in the availability of nitrogen in

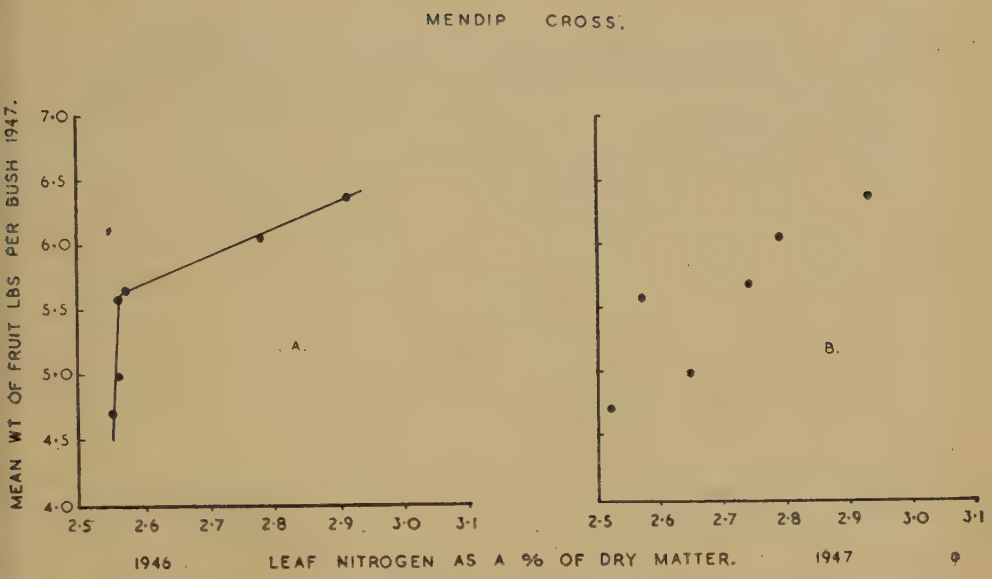

Fig. 1. A. The relationship between leaf nitrogen content for 1946 and the yield of fruit in 1947. B. The relationship between leaf nitrogen content for 1947 and the yield of fruit for the same year. Leaf samples taken in June. Var. Mendip Cross.

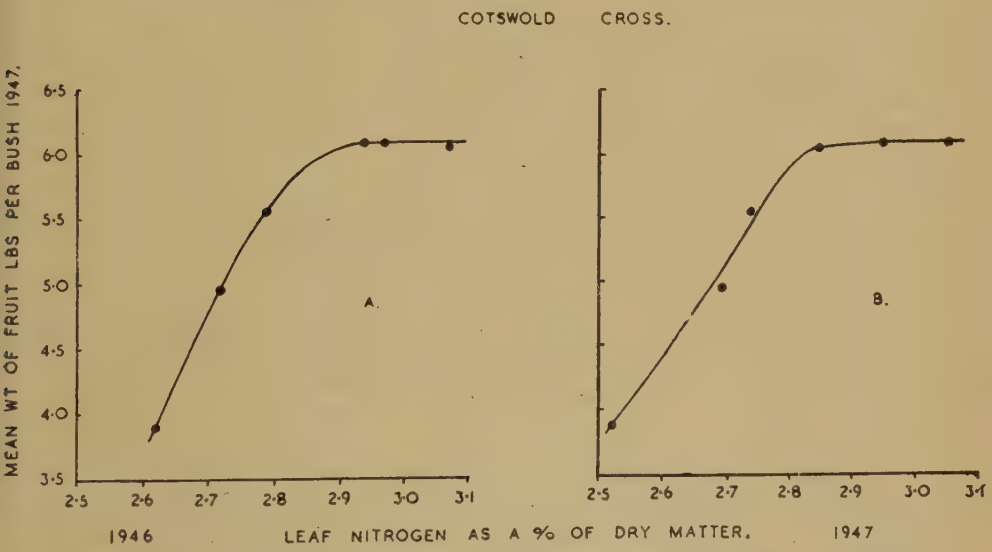

Fig. 2. A. The relationship between leaf nitrogen content for 1946 and the yield of fruit in 1947. B. The relationship between leaf nitrogen content for 1947 and the yield of fruit for the same year. Leaf samples taken in June. Var. Cotswold Cross.

meat and bone meal and nitro-chalk as measured by their effect on the nitrogen status of the leaf.

The relationship between leaf nitrogen content and yield of fruit is shown in figs. 1 and 2.

It would appear from figs. 1 and 2 that the yield of fruit is influenced to a greater extent by the nitrogen nutrition in the previous season than by the

nutrition during the current season. In each case therefore, fig. A probably gives a more valid representation than fig. B. The figures bring out two very interesting points. They show that the two varieties have different nitrogen requirements and that the critical nitrogen value for Cotswold Cross, above which luxury consumption takes place, appears to be in the region of 2·9%. It would appear from fig. 1A that the critical nitrogen value for Mendip Cross has not yet been reached and that this variety would respond to increased nitrogen supply. It is too early yet to regard these results and their implications as anything more than tentative, and too much importance should not be attached to them until more information is available.

SUMMARY.

1. The results of a manurial experiment, for the season 1947, on growth, yield and nitrogen content of the leaves of two varieties of blackcurrants are presented.

2. Treatments had a significant effect on growth, yield of fruit and nitrogen content of the leaf.

3. Composts and stable manure when applied on an equal organic matter basis to 10 tons per acre fresh weight of stable manure did not liberate sufficient available nitrogen for maximum growth and yield of fruit, or maintain an adequate nitrogen status in the leaf.

4. There appears to be relationship between leaf nitrogen content and yield of fruit.

ACKNOWLEDGMENTS.

The sewage sludge and straw-sludge composts were supplied by the Bath City Council (Engineer's Dept.) and the town refuse compost by the London County Council. The co-operation of these Authorities is gratefully acknowledged and best thanks are due to Mr. J. Owens, City Engineer and Mr. N. Priest, Sewage works manager, Bath, and to Mr. Warlow of the L.C.C.

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NOTE ON THE CONTROL OF MAGNESIUM DEFICIENCY OF APPLES.

By T. WALLACE.

Since 1939, experiments on the control of magnesium deficiency of apples have been in progress at a number of centres where the deficiency had produced severe effects, generally to the extent of causing cessation of appreciable terminal shoot growth, varying amounts of die-back of branches, and serious annual leaf blotching and premature defoliation of shoots.

In the early stages of the experiments the remedial methods tried consisted of soil dressings of magnesium sulphate, using calcined Kieserite and magnesian limestone, whilst on a few trees solid injections of magnesium sulphate were also tried. As the experiments proceeded, it was apparent that the soil dressings, although generally effective, were very slow in action and the solid injections useless as curative treatments and hence a number of foliage spraying methods were introduced in an attempt to speed up the rate of recovery.

The experiments at the main centres are still in progress, mainly with a view to perfecting the spraying methods for commercial practice and to following residual effects of the treatments. The effects of the treatments have been assessed annually by visual markings on individual trees for shoot growth, freedom of foliage from magnesium deficiency effects, including defoliation, and by chemical determinations of magnesium in comparable leaf samples.

The relevant field data have proved difficult to obtain for several reasons. Firstly, recording was difficult under war-time conditions and secondly, foliage quality was seriously affected in a number of seasons by frost effects, which also resulted in loss of crops and interacted on severity of symptoms, by the unduly wet season of 1946, which again resulted in abnormal foliage effects, e.g. a curious leaching effect of Cox leaves, and by severe red spider infestations, particularly in 1947, which frequently masked the normal magnesium deficiency effects and almost defoliated many trees.

In spite of these drawbacks, however, the main effects of the treatments are clear and are summarised here so that growers who have serious magnesium deficiency problems may have an opportunity of testing the most effective treatments without delay. It has not yet been possible to make a detailed analysis of the large body of data collected but it is hoped that this will be completed for the next annual report. Since, however, the important point which has emerged from the experiments is the superiority of foliage sprays over soil dressings, examples from the data to illustrate this point are given below.

Soil Dressings.

Annual dressings of magnesium sulphate at 4 or 5 cwt. per acre, using calcined Kieserite with MgO content varying from 30% to 20% during the course of the experiments, have been tested at all centres excepting one where agricultural Epsom salts (14% MgO) at 5 cwt. per acre was used. At all centres excepting two, these dressings have cured the deficiency after a period of three or four seasons.

At one of the failure centres, annual dressings at 5 cwt. per acre calcined Kieserite since 1940, although not resulting in healthy shoot growth and freedom from the deficiency, have produced visible improvement in foliage quality and fruit size. This centre must also be regarded as somewhat abnormal since the affected trees comprise a block sharply defined from the remainder of the plantation and have a ' history ' of headworking which may largely account for their unhealthy condition and slow recovery. At the other, where agricultural Epsom salts has been applied annually at 5 cwt. per acre for four years, the trees remain unsatisfactory, whereas spraying treatment superimposed on the soil treatment has produced quick recovery.

At one centre annual dressings of calcined Kieserite at 4 cwt. per acre were compared with a single dressing of high grade magnesian limestone at 2 tons per acre and here the plots under the two treatments contrasted sharply in growth after three or four years and have remained so, the sulphate plots being markedly superior and the effects from the limestone being relatively small.

Solid Injections.

This treatment was tried at two centres, using calcined Kieserite, and it was obvious that sufficient material could not be introduced into the trees by this method to remedy the deficiency.

Foliage Sprays.

Spraying treatments have been given at six centres, though it is only during the past two or three seasons that the treatments have been carried out in the manner necessary to promote quick recovery. In the earliest experiments only one spray application, using 2% calcined Kieserite and spreader, was made shortly after petal fall stage but this did not produce appreciable effects. Later, following experiences with a similar problem in tomatoes, three to five fortnightly sprayings with the above wash, beginning at petal fall, were arranged and have been applied at four centres. The effects of these treatments were seriously vitiated by continued wet weather during 1946, but in 1947 conditions were favourable and the good effects of spray treatments were clearly visible at the various centres.

Data from two of the centres where the spray treatments were superimposed on soil treatments will suffice to show the efficiency of the sprays.

Centre 1.

Soil treatments.

4 annual dressings of agricultural Epsom salts at 5 cwt. per acre (1944-1947).

Spray treatments.

1945—1 spray of agricultural Epsom salts at petal fall.
1946— ditto Further applications prevented by rain.
1947—5 applications: May 13, 29; June 11; July 2, 11.

Centre 2.

Soil treatments.

1945—Agricultural Epsom salts at 10 cwt. per acre.
1947—Calcined Kieserite at 4 cwt. per acre.

Spray treatments.

1945—1 spray of calcined Kieserite at petal fall.
1946— ditto. Further applications prevented by rain.
1947—5 applications: May 23; June 13, 27; July 1, 25.

RECORDS—AUGUST 27th–29th, 1947.

Centre	Spray and Soil Treatment		Soil Treatment only	
	Shoot growth: vigour marking	Magnesium deficiency marking	Shoot growth: vigour marking	Magnesium deficiency marking
1	3·3 (Fairly good to good)	0·46 (Very slight to trace)	2·9 (Almost fairly good)	2·6 (Severe to medium)
2	3·1 (Fairly good)	0·16 (Less than trace)	2·9 (Almost fairly good)	1·0 (Slight)

The results at the other spray centres support those given in the above table and seem to justify a recommendation that growers with acute problems should try the spraying method, using a 2% solution of agricultural Epsom salts, plus a spreader, and giving four to six fortnightly sprays beginning at petal fall.

It should be added that a 1% spray has been found less efficient than 2% and that beginning early in the season with the spray applications is essential to success. It remains to be seen whether spraying efficiency can be improved by advancing the initial spray date and whether the number of sprayings during the season may be reduced, even in most acute cases—say, to three.

ACKNOWLEDGMENT.

The experiments forming the basis of this note were planned by the writer and mainly carried out by him in association with Mr. J. O. Jones, now an officer in the National Agricultural Advisory Service. Dr. D. J. D. Nicholas carried out the chemical determinations in the later years of the experiments. Substantial help in the field work and with recording was given by Mr. C. R. Thompson, Dr. N. H. Pizer and Mr. W. G. Kent, to whom full acknowledgment will be made in the detailed report.

STUDIES ON THE COMPARATIVE EFFECTS OF DUNG, COMPOST AND INORGANIC FERTILISERS ON CROPS AND SOIL. I. EFFECTS ON YIELDS AND COMPOSITION OF POTATOES AND CAULIFLOWER.

By C. BOULD and E. CATLOW.

In 1945 a manurial experiment was laid down, on a plot of land known to be deficient in magnesium, to test the effect of certain treatments on the growth, yield and nutritional status of some vegetable crops. The primary object was to compare dung and straw-compost with inorganics, but in 1946 the magnesium deficiency symptoms on cauliflower were so severe that it was decided to modify the experiment. In 1947 the plots were split, the plants on one half receiving two foliage sprays of a 2% solution of Kieserite ($MgSO_4.H_2O$). Chemical analyses of the soil and plant material were made in 1947 in order to study the relationship between soil conditions, spray treatment and magnesium status of the leaves. This report will deal with the layout of the experiment and the results for the first three seasons.

In 1945 and 1946 manurial treatments had no significant effect on crop yield (cauliflower) but affected the incidence of magnesium deficiency. In 1947 compost + N.P.K. gave the highest yield of potatoes. Two foliage sprays of a 2% solution of Kieserite increased the yield of tubers and the magnesium content of the leaf.

EXPERIMENTAL.

Layout. The experimental area (¼ acre) was divided into twelve plots, 30 ft. × 30 ft. in size. In the first two years the plots were not further subdivided. The main treatments were :—

1. N.P.K. (Inorganics)
2. Dung
3. Compost (Straw-nitro-chalk)
4. Treatments 1 and 3 combined.

Dung was applied at 10 tons per acre fresh weight, and compost on an equal

dry matter basis for the first year, and afterwards on an equal organic matter basis. The inorganics used were :—

N = 4 cwts. nitro-chalk (15% N) per acre.
or 3 cwts. ammonium sulphate (20% N) per acre
P = 3 cwts. superphosphate (18% P_2O_5) per acre
K = 1 cwt. potassium sulphate (48% K_2O) per acre

Manurial treatments commenced in the spring of 1945. The treatments were randomised in three blocks, A, B and C, each of four plots, 1—4. In 1947 the treatment plots were split, the plants on one half receiving two foliage sprays of a 2% solution of Kieserite at the rate of 100 gals. per acre per spray, i.e. a total of 40 lb. of Kieserite per acre.

The quantities of manure used and date of application are given in Table I.

TABLE I.

Quantities of Organics and Total Nitrogen Applied per Acre During 1945–47.

	1945			1946			1947		
	Date of application	Fr. Wt. Tons	Total N lb.	Date of application	Fr. Wt. Tons	Total N lb.	Date of application	Fr. Wt. Tons	Total N lb.
1. N.P.K.	14/3	—	69·4	10/5	—	69·4	14/4	—	69·4
2. Dung	12/1	10	N.D.	7/1	10	161	27/1	10	106
3. Straw-compost	9/3	15	N.D.	7/1	17·6	165	27/1	11·6	100
4. Compost + N.P.K.	9/3	15	N.D. 69·4	7/1	17·6	234·4	27/1	11·6	169·4

N.D. = Not determined.

Soil.

The soil is a pale reddish-brown non-calcareous heavy sand (20″) overlying fine sand or sandy silt, with drainage slightly impeded. (Series No. 6 of the Research Station soils as classified by Dr. Osmond, L.A.R.S. Annual Report, 1936.) Part of Block C lies on Series No. 8 which is a reddish brown calcareous heavy loam overlying clay. Surface samples were taken from all plots in January 1947. The results of the analyses are given in Table II.

TABLE II.

Analysis of Soils (0–9″) from Plot 17 b, Sampled January 1947. Results Expressed as a Percentage of Air Dry Soil.

Treatment	Plot No.	Exchangeable Mg.	Exchangeable K.	K/Mg. Ratio	Organic Carbon
N.P.K.	A1	0·0049	0·0315	6·4	2·26
	B1	0·0043	0·0239	5·6	2·33
	C1	0·0061	0·0154	2·5	2·69
Dung	A2	0·0065	0·0385	5·9	2·32
	B2	0·0059	0·0312	5·3	2·44
	C2	0·0070	0·0205	2·9	2·27
Compost	A3	0·0050	0·0360	7·2	2·60
	B3	0·0048	0·0210	4·4	2·49
	C3	0·0049	0·0308	6·3	2·69
Compost + N.P.K.	A4	0·0044	0·0364	8·3	2·48
	B4	0·0048	0·0218	4·5	2·60
	C4	0·0052	0·0299	5·8	2·45

RESULTS : SEASONS 1945, 1946, 1947.

1945. Crop Cauliflower, var. Majestic.

The cauliflowers were planted out on 17/5/45. Harvesting began on 17/8/45 and cutting continued until 20/9/45. Records were made on number and weight of all heads harvested, vigour, leaf colour and severity of magnesium deficiency symptoms. Crop yields are given in Table III and information on vigour, leaf colour and deficiency symptoms in Table IV.

TABLE III.

Effect of Treatments on Total Yield and Weight of Marketable Heads. Crop, Cauliflower, Var. Majestic. 1945. Mean Weight in Tons per Acre.

	N.P.K.	Dung	Compost	Compost + N.P.K.	Mean	S.E.
Total Weight	4·25	3·78	3·56	4·35	3·99	0·834
Order	(2)	(3)	(4)	(1)		
Marketable Weight	2·71	2·16	1·82	2·55	2·31	0·235
Order	(1)	(3)	(4)	(2)		

Treatment effects were *not* significant. In general the yield was poor. A large number of plants were blind (27%) or did not mature, and 35% of cut heads were unmarketable.

TABLE IV.

Effect of Treatments on Vigour, Leaf Colour and Magnesium Deficiency Symptoms of Cauliflower, Var. Majestic. Records Taken 14/8/45.

		1 N.P.K.	2 Dung	3 Compost	4 Compost + N.P.K.
Block A	Vigour	3+	2½	2½+	2½+
	Colour	D.G.	P.G.	G.	G.
	Mg. deficiency	L.	L.	S.	M–S
Block B	Vigour	2½	2½	2+	3
	Colour	G.	G.	P.G.	G.
	Mg. deficiency	L–M	M–S	M	L–M
Block C	Vigour	3	2½	2½	3—
	Colour	D.G.	P.G.	P.G.	G
	Mg. deficiency	L.	L–M	M–S	L–M

Vigour—Maximum points = 5 per plot

Colour— DG = dark green : G = green : PG = pale green

Magnesium deficiency symptoms : L = slight = 20% plants affected
M = medium = 40% ,, ,,
S = severe = > 60% plants affected

Growth and Vigour.

N.P.K. > Compost + N.P.K. > dung and compost. Plants receiving dung and compost only had pale foliage indicating nitrogen deficiency.

Magnesium Deficiency Symptoms.

In order of decreasing severity. Compost > dung > N.P.K. and compost + N.P.K. It is interesting to note that the plants also showed symptoms of boron deficiency, and that the order of severity was the reverse to that for magnesium.

1946. Crop, Cauliflower, var. Majestic.

The cauliflowers were planted out on 31/5 to 3/6/46, at the rate of 196 plants per plot. Treatments and records were the same as for 1945 except that magnesium deficiency symptoms were recorded in more detail. Each plant was assessed and placed in one of the following categories each of which was allotted a points value :—

Bad (3 points) = severe necrosis and dwarfing.
Medium (2 points) = general chlorosis.
Slight (1 point) = some chlorosis.
Nil—trace (no points).

The total points value per plot was obtained by multiplying the number of plants in each category by the appropriate points value, and summing the products.

The effect of treatments on vigour and foliage colour is shown in Table V, and the effect of treatments on magnesium deficiency in Table VI.

TABLE V.

EFFECT OF TREATMENTS ON VIGOUR AND FOLIAGE COLOUR OF CAULIFLOWER 7/8/46.

		N.P.K.	Dung	Compost	Compost + N.P.K.
Block A	Vigour	4	4	3+	4
	Colour	D.G.	G.	G.	G.
Block B	Vigour	4	4+	4—	4+
	Colour	G.	G.	P.G.	D.G.
Block C	Vigour	5	4—	3+	4
	Colour	D.G.	P.G.	P.G.	G.

Growth and Vigour.

N.P.K. > Compost + N.P.K. and dung > compost. Plants receiving dung and compost only showed signs of nitrogen deficiency.

TABLE VI.

EFFECT OF TREATMENTS ON MAGNESIUM DEFICIENCY SYMPTOMS IN CAULIFLOWER. ASSESSMENT OF SEVERITY ON A POINTS BASIS. HIGH VALUES INDICATE SEVERE DEFICIENCY.

	N.P.K.	Dung	Compost	Compost + N.P.K.	Total
Block A	167	109	276	289	841
Block B	250	145	254	66	715
Block C	5	58	224	209	543
Total	469	312	754	564	
Order	(3)	(4)	(1)	(2)	

Magnesium symptoms were generally very severe. Plants receiving compost only showed the most severe symptoms whilst plants receiving dung were least affected. The adverse effect of compost was probably due to low availability of nitrogen and the beneficial effect of dung to the magnesium it supplied. Reference to Table II shows that the exchangeable magnesium on plots receiving dung was greater than all other plots, with the exception of C1.

Crop Yield.

The effect of treatments on crop yield is shown in Table VII.

TABLE VII.

Effect of Treatments on Total Yield and Weight of Marketable Heads of Cauliflower. 1946. Mean Weight in Tons per Acre.

	N.P.K.	Dung	Compost	Compost + N.P.K.	Mean	S.E.
Total Weight Order	4·51 (1)	3·39 (3)	3·00 (4)	4·15 (2)	3·78	0·46
Marketable Weight Order	1·75 (1)	1·53 (2)	1·13 (4)	1·49 (3)	1·47	0·39
Marketable Heads as a % of Total Weight Cut	38·4	45·1	37·8	35·9	39·1	

Treatment effects were *not* significant. The order of yields was almost the same as in 1945. The crop generally was poor with a high percentage of unmarketable heads. Although dung reduced greatly the severity of magnesium symptoms its effect on yield was not so marked probably because of low nitrogen availability.

1947. Crop, Potato.

Three varieties of potato were used namely: Majestic, Red King and Kerr's Pink. These varieties were chosen because of their differential response to nutritional deficiencies. At Long Ashton Majestic is always least affected by unfavourable manurial treatments, as judged by foliage symptoms, and Red King most, whilst Kerr's Pink is notable for the striking leaf patterns produced by deficiencies. The yield from Red King is always much less than from the other two varieties.

The varieties were planted in alternating units of three rows running E to W on 12/5/47, each plot containing three rows of each variety.

The general manurial treatment was the same as in 1946 except that ammonium sulphate was used instead of nitro-chalk. Prior to earthing up, each plot was divided across the rows into two equal parts, the plants on one half of each receiving two sprays of a 2% solution of Kieserite ($MgSO_4.H_2O$) at the rate of 100 gals. per acre per spray. (Estol H was used as a spreader.)

1st spray applied on 21/6/47: 2nd spray applied on 4/7/47.

Each half plot contained 72 recorded plants.

General Observations 21/6/47.

Plants receiving compost only were less vigorous and showed magnesium deficiency symptoms more than plants receiving other treatments. Best plants for vigour and freedom from deficiency symptoms were on plots receiving N.P.K. and compost + N.P.K.

Kerr's Pink plants were most forward and showed most symptoms. Those of Red King were intermediate as regards vigour and symptoms and Majestic were least forward and showed least symptoms. The incidence and severity of magnesium deficiency symptoms for the varieties Kerr's Pink and Red King are shown in Table VIII.

TABLE VIII.

PERCENTAGE OF POTATO PLANTS SHOWING MAGNESIUM DEFICIENCY SYMPTOMS PRIOR TO THE 1ST SPRAY. 21/6/47.

Variety	Block	(1) N.P.K.	(2) Dung	(3) Compost	(4) Compost + N.P.K.
Kerr's Pink	A	23·8	28·3	67·4	30·4
	B	21·7	26·1	40·4	Nil
	C	Nil	9·0	45·6	8·7
Mean		14·81	21·16	51·20	12·95
Red King	A	2·7	11·1	52·3	34·1
	B	29·5	14·6	9·2	2·5
	C	Nil	9·5	9·3	2·8
Mean		10·57	11·72	23·85	13·68

It is interesting to note that plants on plots A3 and A4 were most severely affected whilst plants on plot C1 were free from symptoms. Soils from A3 and A4 had the highest exchangeable K/Mg ratio whilst soil from C1 had the lowest ratio. This relationship is brought out in *Figs.* 1, 2 and 3.

Owing to the danger from potato blight the plants had to be sprayed with Bordeaux Mixture before a second assessment of magnesium symptoms could be made. The visual response to the magnesium spray treatment could not therefore be recorded. The deficiency symptoms however, did not increase to any considerable extent on any plants. In future it is proposed to apply the first magnesium spray before any symptoms appear.

The tubers were lifted and weighed on 16/10/47. The analysis of variance on yields showed that the effect of varieties and manures was significant at 1% level of *P*, and the effect of magnesium spray treatment at 5% level of *P*. None of the interaction effects was significant. A summary of the significant effects is given in Tables IX, X and XI.

TABLE IX.

EFFECT OF MANURIAL TREATMENT ON THE YIELD OF POTATOES. MEAN WEIGHT IN LB. PER PLOT. 1947.

N.P.K. (1)	Dung (2)	Compost (3)	Compost + N.P.K. (4)	S.E.	Sig. Difference at 1% *P*
58·3	54·7	59·8	64·3	1·58	6·00

Treatment 4 > 1 and 2 (at 1% level of *P*)

TABLE X.

EFFECT OF VARIETY ON YIELD OF POTATOES. MEAN WEIGHT IN LB. PER PLOT. 1947.

Red King	Majestic	Kerr's Pink	S.E.	Sig. Difference at 1% *P*
44·7	62·2	70·9	1·37	5·19

Kerr's Pink > Majestic > Red King (at 1% level of *P*).

TABLE XI.

EFFECT OF MAGNESIUM SPRAY TREATMENT ON YIELD OF POTATOES. MEAN WEIGHT IN LB. PER PLOT. 1947.

Unsprayed	Sprayed	S.E.	Sig. Difference at 5% *P*
56·9	61·6	1·12	3·18

Sprayed > unsprayed (at 5% level of *P*)

It is surprising that compost only did not reduce the yield of potatoes in view of the low availability of nitrogen and severity of magnesium deficiency symptoms. In this respect the potato behaved differently to the cauliflower. The effect of spray treatment on yield was small but significant. The response might have been greater had the first spray been applied earlier. Experience with magnesium sprays on apple trees emphasises the importance of early application for maximum absorption and response.

Magnesium Content of Potato Leaves.

In order to check the absorption of magnesium through the aerial parts of the potato, and to obtain information on the relationship between magnesium in the soil and uptake by the plant, leaf samples were taken from the mid-stem region and analysed for total magnesium. The results for the variety Majestic (least susceptible) and Kerr's Pink (most susceptible) are given in Table XII.

TABLE XII.

EFFECT OF MANURIAL TREATMENTS AND MAGNESIUM SPRAYS ON THE MAGNESIUM CONTENT OF POTATO LEAVES. MID-STEM POSITION. 29–30/7/47. TOTAL MgO AS A PERCENTAGE OF DRY MATTER.

Treatments		Majestic		Kerr's Pink			
		Sprayed	Unsprayed	Sprayed	Unsprayed	Total	Mean
N.P.K.	(1) A	0·520	0·512	0·318	0·242	5·653	0·471
	B	0·395	0·406	0·341	0·283		
	C	0·913	0·822	0·461	0·440		
Dung	(2) A	0·571	0·522	0·390	0·327	5·597	0·466
	B	0·503	0·474	0·415	0·374		
	C	0·585	0·578	0·455	0·403		
Compost	(3) A	0·501	0·446	0·406	0·278	4·983	0·415
	B	0·510	0·466	0·347	0·307		
	C	0·544	0·453	0·387	0·338		

TABLE XII (*continued*)

Treatment	Majestic		Kerr's Pink			
	Sprayed	Unsprayed	Sprayed	Unsprayed	Total	Mean
Compost (4) A	0·471	0·450	0·296	0·266		
+ B	0·681	0·549	0·420	0·325	5·249	0·437
N.P.K. C	0·583	0·481	0·447	0·333		
Total	6·724	6·159	4·683	3·916		
Mean	0·560	0·513	0·390	0·326		

The analysis of variance showed that varietal differences were significant at 1% level of *P* and differences due to spray treatment at 5% level of *P*. Differences due to manurial treatment and all interactions were *not* significant. The overall values for sprayed and unsprayed plants are given below :

Sprayed	Unsprayed	S.E.	S.D.
0·4753%	0·4198%	0·0182%	0·0523%

DISCUSSION.

The Relationship Between Exchangeable Magnesium, Deficiency Symptoms and Magnesium Content of the Plant.

The availability of an exchangeable cation in the soil is a function of the degree of saturation of the colloid with the particular cation, as well as of the amount of the cation present. Availability further depends on the nature and proportion of the other ions adsorbed by the colloid, and on the nature of the colloid itself. Other factors which influence absorption are the nature of the plant and the rate at which exchangeable ions are replenished from non-exchangeable sources.

According to Cooper *et al.* (1) the dominant ion in the exchange complex is potassium and the ratio of potassium to magnesium present should have a profound influence on the absorption of magnesium. One would not expect therefore, a simple relationship between the magnesium content of a soil, the uptake of magnesium by the plant, and the severity of deficiency symptoms.

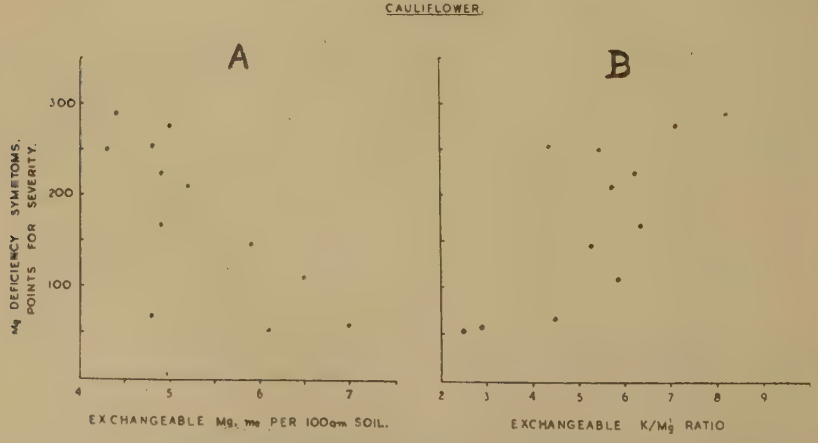

Fig. 1. A. The relationship between exchangeable magnesium and the severity of magnesium deficiency symptoms in cauliflower. B. The relationship between exchangeable K/Mg ratio and magnesium deficiency symptoms.

Figs. 1a and 1b show the relationship between exchangeable Mg and K/Mg ratio in the soil, and the severity of magnesium deficiency symptoms in cauliflower.

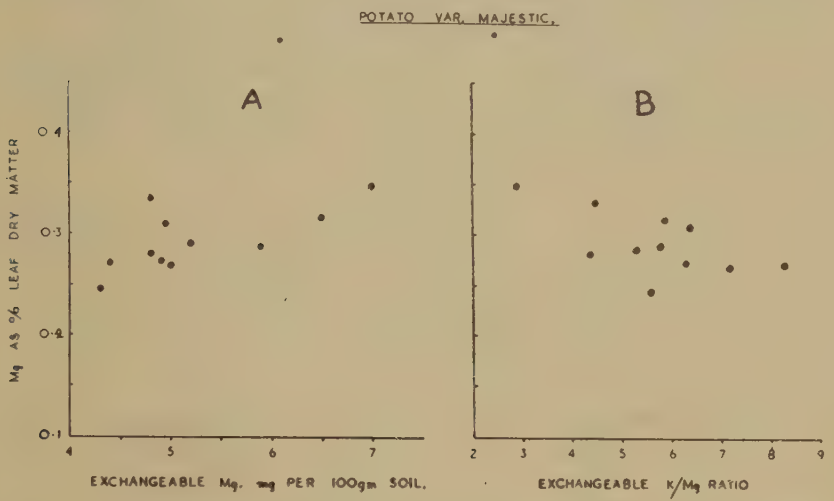

Fig. 2. A. The relationship between exchangeable magnesium and the magnesium content of potato leaves. B. The effect of exchangeable K/Mg ratio on the magnesium content of potato leaves, var. Majestic.

Figs. 2a and 2b, 3a and 3b show the relationship between exchangeable Mg and K/Mg ratio and the magnesium content of potato leaves.

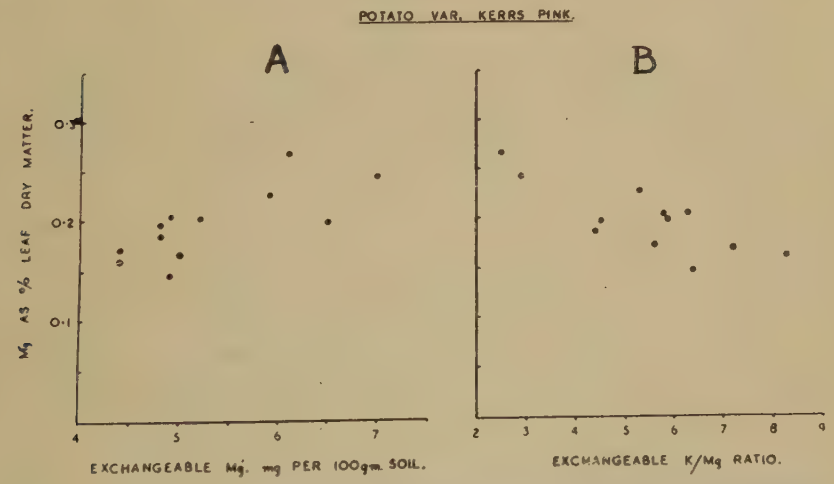

Fig. 3. A. The relationship between exchangeable magnesium and the magnesium content of potato leaves. B. The effect of K/Mg ratio on the magnesium content of potato leaves, var. Kerrs Pink.

The results are in keeping with the preceding remarks on soil-plans relationships. It will be seen that as the K/Mg ratio in the soil increases the absorption of magnesium by the plant falls and the deficiency symptom increase in severity. On the other hand, providing the exchangeable potassium

remains reasonably constant the uptake of magnesium by the plant increases with increased exchangeable magnesium. In order, therefore, to interpret soil conditions in relation to magnesium deficiency in plants it is necessary to determine both exchangeable magnesium and potassium and possibly total exchange capacity. According to Prince *et al.* (2) if the magnesium constitutes less than 6% of the total exchange capacity of a soil plants will respond to magnesium application. In the present investigation the exchangeable magnesium constituted approximately 3% of the total exchange capacity.

SUMMARY.

1. A description is given of the lay-out of a field experiment designed to test the effects of organic and inorganic manures on the growth, yield and nutrient status of certain vegetable crops, and to elucidate, over a term of years, the cumulative effects of the treatments on soil fertility.

2. Results for the first three seasons of the trial are listed with special reference to the relationships between soil conditions and magnesium status of the plant.

3. An account is given of the effect of two sprayings with a 2% solution of kieserite ($MgSO_4.H_2O$) on the yield, magnesium content of the leaf and severity of magnesium deficiency symptoms in potatoes on the experimental plots.

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THE PRODUCTION OF MOLYBDENUM DEFICIENCY IN PLANTS IN SAND CULTURE WITH SPECIAL REFERENCE TO BRASSICA AND TOMATO CROPS.

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The characteristic field disorder known as Whiptail of cauliflower and broccoli plants is widespread in distribution and may occur in acid and neutral soils (1), (2), (3), (4), (5). Recent reports in the literature indicate that this disorder may be controlled by the application of molybdenum compounds to the soil (6), (7), (40). The need of leguminous plants also for this element in the field has been demonstrated recently (8), (9), (10), (11) and particularly in poor soil under conditions of low soil nitrogen status (12).

Other workers using water culture methods have shown the need for molybdenum in tomato (13), asparagus, mustard, lettuce (14), oat (15), plum seedling (16) and for legume nodulation (17). Although highly purified nutrient salts were used in many of these experiments the purification methods were not specially effective for the elimination of molybdenum (15), (18).

The work described here was begun with the twofold purpose of developing a new method for the purification of nutrient salts free from molybdenum and the reproduction of " Whiptail " symptoms in cauliflower using a refined sand culture technique.

EXPERIMENTAL.

Materials and Methods.

The sand used was a relatively pure silica sand obtained from Leighton Buzzard, Bedfordshire, and 90% of which was retained between 24 and 40 mesh sieves. This fraction, which was used in the experiment, was relatively low in molybdenum-containing impurities most of which were retained on the 24 mesh sieve (19). The sand was further purified by continuously circulating 250 lb. batches with steam for about 5 hours in the presence of 12% hydrochloric acid (A.R. grade) and 0·5% oxalic acid (hydrated) in an automatic apparatus which has been described in detail elsewhere (19). Each batch was treated twice and leached free of acid before use with a purified basal nutrient solution until the pH was unchanged on standing overnight.

The purified sand was contained in pyrex glass beakers of five litre capacity, each equipped with a central drainage hole of one inch diameter in the bottom. This hole was covered with a pad of glass wool which was overlain by a small glazed perforated filter disc. The beakers were steamed with the vapour of constant-boiling hydrochloric acid before use. In a parallel experiment ten-inch clay pots painted with three coats of pure bitumen solution were used in place of the pyrex glass beakers. In all other respects however the experimental details were identical.

Water was obtained by a single redistillation in a continous acting pyrex glass still, using water obtained from tinned copper stills. The molybdenum content of the water prior to redistillation was 0·0003 p.p.m.

The method used for the purification of the basal nutrient salts was based on the procedure developed by Scott and Mitchell (20) for the concentration of trace elements for spectrographic analysis by co-precipitation with 8-hydroxyquinoline and iron (or aluminium). The basal stock solutions of nutrient reagents consisted of 2-molar calcium and potassium nitrates, molar sodium dihydrogen phosphate and 1·5-molar magnesium sulphate. These were purified as follows :—Calcium nitrate was prepared from glass distilled nitric acid and re-precipitated calcium carbonate while the others were available either as " batch analysed " A.R. grade or as normal recrystallised grade ; these were first recrystallised twice, with the addition of purified alcohol to greatly enhance the yields (19). Solutions of each of the four reagents were prepared such that the requisite weight for 2 litres of solution was dissolved in about 1700 ml. of water. Redistilled hydrochloric acid was added to each to adjust the pH to 1·8 and ferric chloride than added equivalent to 40 mg. of iron, followed by the equivalent weight of 8-hydroxyquinoline. *N*. potassium hydroxide solution (A.R. grade) was added with continual stirring until the solution had a pH of 4·5-5·0 as determined by a glass electrode. The solution was left to stand overnight, filtered on a Buchner funnel, and the volume made up with glass-distilled water to 2 litres in acid-cleaned pyrex glass bottles. Ferric citrate was used in the nutrient solution to supply iron. This was prepared by first extracting an acidified solution of ferric chloride (containing 47 g. per litre of iron) with toluene-3:4-dithiol in amyl acetate to remove molybdenum (21) followed by neutralisation with a glass-distilled ammonia solution in the presence of about 20 mg. of 8-hydroxyquinoline until the ferric complex was precipitated. The solution was filtered and the remainder of the ferric irons were precipitated with more ammonia ; the ferric hydroxide was converted to the citrate by boiling in a solution of recrystallised A.R. grade citric acid.

The usual micro-nutrient constituents, boron as boric acid, and manganese,

copper and zinc as sulphates, were supplied as A.R. grade compounds from a separate micro-nutrient solution; a second micro-nutrient solution was prepared in which molybdenum was also included as A.R. ammonium molybdate. The same principal stock solutions were used to prepare both the complete and the " molybdenum omitted " nutrient solutions by dilution with glass distilled water to produce the following composition :—

Reagent	g. in 20 litres
$Ca(NO_3)_2$	10·92
KNO_3	6·66
$NaH_2PO_4 2H_2O$	4·16
$MgSO_4\ 7H_2O$	7·36
$Fe(C_6H_5O_8)$	0·49

Approximate concentrations as milli-equivalents per litre were : Ca^{++} 6·67 ; K^+ 3·33 ; Na^+ 1·33 ; Mg^{++} 3·0 ; PO_4'' 4 ; NO_3' 10 ; SO_4'' 3 ; Fe^{+++} 0·3 ; Mn^{++} 0·02 ; Cu^{++} 0·002 ; Zn^{++} 0·002 ; BO_3'' 0·01 ; pH 5·5-6. The molybdenum content of the complete nutrient was 0·015 p.p.m. Mo or 0·0002 milli-mol.

Seeds of savoy cabbage, cauliflower (Majestic) and tomato (Market King) were germinated on glass wool with purified nutrient solution. The seedlings were transferred to the final sand cultures when the first true leaf was beginning to expand. Three or four seedlings were transplanted into each beaker on 27/6/46, and thinned two weeks later to one or two plants. Mustard seeds were sown directly in the experimental beakers on 12/9/47 following oat plants grown in the same experiments and only reported here with regard to yields of straw and grain.

During the course of the growing period the nitrate status of the foliage and the osmotic pressure of the guard cells of molybdenum deficient plants were examined and compared with those of the controls (22). At the end of the season the tomato, brassicae and mustard were harvested and analysed for their total molybdenum content by the method given in detail below.

Sampling technique for Ash Analysis.

The young and old leaves were sampled in the tomato and mustard plants. In the savoy and cauliflower the first upright leaves outside the incurled leaves were used (23). The top and bottom stem portions were also sampled in tomato and mustard. The material was thoroughly cleaned with a muslin cloth so as to remove dust particles adhering to the outer surfaces.

The material was dried at 98°C. for 48 hours in an aerated oven and then crushed by hand when still hot, using rubber gloves. The finely crushed dry matter was then stored in special inert plastic containers.

Wet digestion of Dry Matter.

The wet digestion method used for the destruction of organic matter has been described previously (24). It consisted of ashing finely powdered material in the presence of a mixture of oxidising acids, viz. $HClO_4$, HNO_3 and H_2SO_4. The quantities used were as follows :—to 5 g. of dry matter in a 400 ml. pyrex beaker with a watch glass was added 50 ml. of redistilled conc. HNO_3 (M.A.R. grade), and this was heated on an Argand burner slowly at first but more vigorously later. The heating was continued for about 30 mins. until the volume had

been reduced to approximately 20 ml., when most of the ammonia had been removed. After cooling, 5 ml. of perchloric acid and 2 ml. of sulphuric acid were added and heating continued until the "frothing" stage, when dehydration of the silica occurred. Heating was continued on a low gas, to prevent charring, and more vigorously later when the organic matter had been oxidised to remove excess perchloric acid. Hot glass distilled water was then added and the beakers were placed on the hotplate for 15 mins. and the solution kept at a temperature of 60°C. The ash solution was allowed to cool and then filtered through a Whatman No. 42 paper into a graduated cylinder fitted with a ground glass stopper, and after adding 3 ml. of conc. HCl the volume was made up to 50 ml. with glass distilled water.

Chemical Method.

The chemical method used in the determination of Mo is a modification of Marmoy's method (25) as reported by Piper (26). Glass distilled water and A.R. reagents were used throughout.

To the 50 ml. ash solution in the graduated cylinder was added 5 ml. of conc. HCl followed by 3 ml. of a 20% NH_4CNS solution, when a red colour due to ferric thiocyanate was formed. This was discharged by adding 3 ml. of a 10% $SnCl_2$ in 10% HCl solution and the residual purple colour was that of molybdenum thiocyanate. Should the red colour, due to iron, persist, more $SnCl_2$ must be added to reduce ferric iron but for the plants tested, 3 ml. was sufficient.

The diethyl ether solvent used by Marmoy (25) has the dual disadvantage of being partially soluble in water and in being volatile, and these preclude its use in a Spekker method. A range of other solvents were investigated and one of the most satisfactory was a 1:1 mixture of amyl alcohol and amyl acetate. Five ml. was added and after shaking vigorously the molybdenum thiocyanate was extracted completely from the aqueous phase.

The solvent containing the molybdenum thiocyanate was pipetted into a centrifuge tube and spun for 10 mins. at 2,500 revolutions per minute.

The Mo levels were determined by means of the Spekker Absorptiometer using micro-cells and Hilger violet glass filters with a water setting of 0·5. A calibration diagram was prepared using known standards ; in the presence of 500 μg Fe^{+++} (27) the effective range being 1 to 10 μg. Mo per 5 ml. Blank determinants were always included and in most instances these gave a Spekker reading of approximately 0·5 denoting the absence of Mo.

RESULTS.

Visual Observations.

Cauliflower, savoy, mustard.

During the early stages of growth, plants in both pyrex beakers and clay pots showed similar and equally severe symptoms of molybdenum deficiency. Distinct recovery was obvious in plants in the clay pots as the roots reached the walls of the container at the four weeks stage. Recovery was sufficiently good to enable the tomato plants to fruit normally and to allow the cauliflowers to produce good flower heads. These observations indicated that the clay pots were able to supply sufficient molybdenum for growth in contrast to the pyrex beakers in which the symptoms, dexcribed below, persisted.

Pronounced visual symptoms appeared rapidly in the cultures receiving the "molybdenum omitted" treatment. The symptoms in cauliflower and

savoy cabbage began as marginal and intervenal pale yellow-green mottling of the older leaves ; the foliage had a " watersoaked " appearance suggestive of material " cleared " in glycerine. The mottling was followed rapidly by the incurling and withering of the margins and tips of the leaves and the older leaves finally shrivelled and dropped off. Some of these effects may be seen in seedling savoy cabbages shown in fig. 1 and were obvious at the 3 week stage.

It was noteworthy that in both cauliflower and savoy (and also in the tomato) the cotyledons remained bluish green in colour for several weeks although marked chlorotic symptoms had appeared in the middle and old leaves.

Signs of gradual recovery were apparent about six weeks after transplanting, particularly in the savoy cabbage. This recovery permitted the plants to grow to a more adult stage when the following effects developed.

At ten weeks, one cauliflower plant which had partially recovered in vigour developed foliage in which the lateral development of the lamina was partially suppressed ; the resultant elongated leaves had a narrow irregular, wavy outline and extensive grey-brown withered areas developed between the veins. Younger leaves developed with defective laminae and some showed the extreme condition of only smooth, bare petioles. Death of, or possible abortion of the growing point then occurred leaving short rudimentary stumps with brown tips. The bare petioles continued to elongate rapidly : cf fig. 2. These symptoms appeared identical with the severe cases of " Whiptail " observed in the field.

In the remaining plants the middle leaves also developed abnormally. In these leaf tips turned brown and withered and the petioles were stunted and almost devoid of lamina except for the stipule-like portions around the leaf base. These petioles also continued to elongate but less rapidly than in the plant already described. Death of the growing point also occurred in these plants (Fig. 3) and in one this effect appeared suddenly (as far as could be judged) when the youngest, almost rudimentary leaves " deliquesced " overnight to a brown gelatinous mass which after drying revealed a smooth, almost formless stump in the centre of the plant. In spite of the death and collapse of the youngest leaves the older leaves still remained turgid although they were pale green and diffusely mottled.

The savoy cabbage was less spectacular in the later stages of the deficiency. The early mottling persisted in the older leaves and the plants failed to form a " heart." The petioles had a marked tendency to point in a downward direction and the habit remained " open." Both young and middle leaves showed a discontinous brown marginal necrosis that resulted in an irregular outline and in some plants led to narrow ragged leaves ; the leaf tip turned brown and expansion was checked. Death of the growing point had not occurred by the end of November but in two plants axillary sprouts developed and the young leaves of these and of several of the growing points also turned brown and died ; in others the young petioles collapsed before the young laminae expanded. Towards the end of November purplish lesions, suggestive of manganese toxicity symptoms, appeared along the adaxial side of the midrib of some of the older leaves.

As noted above seeds of white mustard were sown later in the season on 12/9/47 in sand from which oat plants (Spring oat S187) had been grown previously without producing the characteristic symptoms noted by Piper (15) using the Algerian oat, although the yields of straw and grain were reduced by lack of molybdenum as shown in Table 1.

TABLE I.

Mean Yields in g. of Oat Straw and Grain for Control and Molybdenum Deficient Cultures Harvested on 2/9/47 after 12 Weeks Growth.

	Straw (10 plants)	Grain (10 plants)
Pyrex glass beaker with molybdenum	49·5	10·9
Pyrex glass beaker without molybdenum	22·7	3·85
Clay pots with molybdenum	55·0	8·4
Clay pots without molybdenum	15·9	2·2

The mustard however showed well-defined visual symptoms that were analogous with the early symptoms of the cauliflower, savoy and tomato and confirmed results obtained by Arnon (14). The general appearance of the foliage was pale green or yellow green. Symptoms first appeared in the middle expanded leaves as a yellowish-green marginal band near the apical region of the leaflets. This was followed by a forward curling at the margin and the later appearance of whitish-brown marginal scorch. In the older leaves the whole lamina eventually turned whitish brown and withered. In one plant the appearance of brown lesions, closely resembling those produced by manganese toxicity (28), along the stem was observed : these were absent in the control plants.

Tomato.

The symptoms observed in the tomato confirmed those described by Arnon and Stout (13) and were visible within two or three weeks after transplanting the seedlings. The first symptoms appeared in the older leaves. They showed yellow-green mottling diffusely between the main veins and had upcurled margins ; necrosis and shrivelling of leaf tips occurred, beginning in the tip leaflet and later spreading to all leaflets. The old leaves were ultimately completely withered and had a dry, pale brown, papery appearance ; the petioles tended to point in a downward direction. Although these symptoms progressed up the plant the shoot and growing point continued to elongate slowly. The upper leaves were pale yellow green and showed mottling and scorching. The flower trusses generally withered but where setting occurred there was only a small single fruit on a truss as compared with clusters of large fruits in the controls.

Chemical Data.

Molybdenum Deficiency and Nitrate Status.

The reports in the literature that molybdenum is particularly important to nitrogen fixing organisms (29), (30), (31), (32) and that in the absence of molybdenum, utilisation by *Aspergillus niger* of ammonium nitrogen is more efficient than of nitrate nitrogen (33), (34), led to the examination of the nitrate status of tissue extracts (22) of freshly sampled leaves of the plants. The

results are shown in Table II where it will be seen that marked accumulation of nitrate occurred in leaf (petiole) tissues of most of the plants starved of molybdenum. and that where clay pots were used for the molybdenum treatment, intermediate values were obtained. Savoy cabbage, however, did not show such variation in nitrate status and for this no explanation can be given at present.

Portions of epidermal tissue from the leaves of control and molybdenum omitted plants were examined in a series of glucose solutions of known concentrations. Approximate osmotic pressure values were deduced from the concentration of glucose producing slight plasmolysis of 50% of the stomatal guard cells. The results are given in Table II. There was an increased osmotic pressure in the leaves of those plants which also showed accumulation of nitrates.

TABLE II.

NITRATE CONTENT AS P.P.M. IN THE MORGAN'S EXTRACT OF FRESH LEAF TISSUES AND APPROXIMATE OSMOTIC PRESSURE IN ATMOSPHERES OF STOMATAL GUARD CELLS OF CONTROL AND MOLYBDENIUM DEFICIENT PLANTS.

	Crop.									
	Tomato			Cauliflower			Mustard		Savoy Cabbage	
Date sampled for nitrate content	—Mo in glass beakers	—Mo in clay pots	+Mo control	—Mo in glass beakers	—Mo in clay pots	+Mo control	—Mo in glass	+Mo beakers	—Mo in glass beakers	+Mo control
11/9/47	240	50	nil	400	150	20	—	—	165	205
6/10/47	170.	—	5	100	—	45	100	15	60	70
Osmotic pressure 12-14/11/47	2·24		0·90	13·44		10·08	8·96	3·92	4·48	10·08

Results of Ash Analysis of the Plants.

Plants grown in clay pots were analysed to determine how much more molybdenum had been absorbed from the medium as compared with similar plants grown in glass beakers. The results of these analyses are given in Tables III and IV.

TABLE III.

MOLYBDENUM CONTENT (IN P.P.M. OF DRY MATTER) OF CAULIFLOWER, SAVOY AND MUSTARD.

Nutrient Treatments	Cauliflower leaf (1st Upright)	Savoy leaf (1st Upright)	Mustard leaf		Mustard stem	
			Young	Old	Young	Old
+Mo (Control)	6·2	5·6	3·2	2·0	1·6	1·3
—Mo (clay pots)	1·3	1·7	—	—	—	—
—Mo (glass beakers)	0·25	0·36	1·0	0·6	0·8	0·61

TABLE IV.

MOLYBDENUM CONTENT (IN P.P.M. OF DRY MATTER) OF YOUNG AND OLD LEAVES AND STEMS OF TOMATO

Treatment	Leaves		Stem	
	Young	Old	Young	Old
+Mo (control)	3·0	2·3	2·3	1·6
—Mo (clay pots)	1·1	1·2	1·2	1·3
—Mo (glass beaker)				
a. Plant injected with dilute Mo solution	0·5	0·36	0·23	0·24
b. Plant not injected (in same beaker)	0·23	0·20	0·21	0·25
—Mo (separate glass beaker replicates)	0·18	0·20	0·13	0·12

The results show that the molybdenum contents of all of the control plants were outstandingly higher than of the molybdenum-omitted plants. The molybdenum contents of the leaves of the cauliflower, savoy and tomato control plants were higher than those of mustard. Plants grown in clay pots without added molybdenum contained more molybdenum than those grown in glass beakers, but less than the controls given molybdenum. Tomato plants not given molybdenum contained the lowest amount of this element (0·2-0·25 p.p.m.) whereas the mustard had the highest content (0·6-1·0 p.p.m.) The cauliflower plants supplied with Mo contained the highest molybdenum content (6·2 p.p.m.) and the mustard the lowest (2·0-3·2 p.p.m.) in the leaves.

The old and young stem portions usually contained similar molybdenum contents and with a few exceptions the stems contained less molybdenum than leaves taken from corresponding parts of the plants.

The foliage of the tomato plant which had been injected through an old leaf contained more molybdenum than corresponding leaves taken from a non-injected plant grown in the same beaker whereas the molybdenum contents of the corresponding stem regions of both plants were similar.

Leaf Injection and Painting Experiments with ammonium molybdate solutions.

In order to obtain further evidence that the effects described were due to molybdenum deficiency some leaf painting and injection experiments were made. A pair of tomato plants grown in the same beaker was selected four weeks after transplanting when both showed pronounced symptoms; one was injected on 25/7/47 by removing the apical leaflet of a lower leaf and inserting the stalk into a light capillary tube out from a small reservoir containing a solution of 10 p.p.m. molybdenum as A.R. grade ammonium molybdate. The stalk fitted closely into the capillary which was kept horizontal and no leak or dripping occurred. In 48 hours the mottling had disappeared from all leaves above the injected leaf of the treated plant only and the colour changed from pale yellow-green to dark green. Rapid elongation occurred and all fresh growth was a normal dark green, the leaflets were flat instead of being upcurled at the margins as in the untreated plant and fruiting occurred normally. The heights of the injected and untreated plants were 15 and 18 cms. respectively at the time of the experiment, and 25 days later they were 63 and 50 cms. respectively; this represented an overall increase

of 50 % in the growth of the injected plant. A slight recurrence of symptoms appeared in the latter by the end of November and shoot elongation again slowed down. It was estimated that the total amount of molybdenum injected did not exceed 0·01 mg. In other experiments, made by painting leaf surfaces of tomato and savoy cabbage or by placing a drop of solution on a small incision in a leaf vein of cauliflower plants showing severe symptoms, with a solution containing 100 p.p.m. of molybdenum, there were similar rapid recoveries but symptoms reappeared in the Brassicae after four to five weeks, following this type of application.

Influence of 8-Hydroxyquinoline.

Although control cultures receiving molybdenum produced normal plants and were supplied with nutrient solution from the same source as those deficient in molybdenum it was considered desirable to examine whether any of the effects described had resulted from the presence of traces of the 8-hydroxyquinoline added during the purification of the stock nutrient solutions, although it was expected that most of that added would have been removed by the precipitation technique. In order to test this point an additional series of cultures was set up in which 8-hydroxyquinoline was present in a much greater concentration in the complete nutrient, namely 3·6 p.p.m., this being the concentration that would have resulted had none of the 8-hydroxyquinoline been removed in the purification technique. The plants grew normally with this solution and showed no toxic effects, and it was concluded that the results observed were not due to the action of traces of 8-hydroxyquinoline remaining in the nutrient solution after purification.

DISCUSSION.

The observations described here were made during a single year's work, but certain points seem sufficiently outstanding to merit discussion.

The agreement with the results of previous workers (13), (14), the responses to injection and other methods of leaf application of dilute solutions of ammonium molybdate, and the results of the ash analyses of the plant material afforded evidence that the effects produced were in fact due to omission of molybdenum, whilst extraneous interactions from 8-hydroxyquinoline appeared to be absent. It is clear that these symptoms are reproducible when neither the container nor the sand affords a supply of molybdenum. Visual and chemical comparison of plants grown in painted clay pots and pyrex glass beakers from which molybdenum was withheld, showed that the former allowed of recovery, and supplied sufficient molybdenum for apparently normal growth, whereas the glass beakers and all other aspects of the technique appeared satisfactory for demonstrating Mo deficiency.

The morphological distribution of deficiency symptoms in mustard suggested that for this plant limited supplies of molybdenum could be readily translocated from older leaves to younger ones for re-utilisation in the growing shoot. This was confirmed by the chemical analyses. A similar distribution of symptoms was clearly evident in tomato but the total Mo content of the leaves of deficient plants was much lower than for mustard and the differences between the young and old leaves were less marked. The cauliflower and savoy cabbage plants also showed deficiency effects in the older leaves in the earlier stages of growth, but as the deficiency developed, however, (subsequent to a temporary recovery), the most severe symptoms appeared in the younger parts and ultimately led to death of the growing point. Symptoms observed

in lettuce by Warington (35) were mainly in the " middle " leaves, a condition that might be analogous with effects shown more particularly by savoy cabbage in these experiments, whilst for mustard the later sowing and consequently slower growth conditions do not at present justify greater emphasis on the particular response of this crop. The symptoms shown in the Cruciferous species therefore suggest that the re-distribution of molybdenum in deficient plants may occur less readily than in tomato and that it may be insufficient to prevent death of the growing point if other circumstances are favourable to rapid growth. Moreover the importance of molybdenum may vary somewhat during the life history of the plant as is suggested by the effects of molybdenum deficiency on flowering and seed formation in cauliflower, on fruit formation in tomato, and on yield of grain in oat. Bertrand (36), (37), has found that the Cruciferous species are relatively rich in molybdenum and that the seeds in particular accumulate this element. This mobility of limited amounts of molybdenum in the deficient plants may also vary with age, or stage of development in some species, and the long period during which the cotyledons of deficient seedlings remained green may be significant in this respect. The elucidation of these points must await further experiments.

Two other points call for comment at this stage. The capacity for continued extension shown by many practically bare petioles after death of the growing point had occurred was particularly noteworthy. The reason for for the elongation is not known. It was also observed that old leaves of molybdenum deficient savoy cabbage plants seemed to be unusually large as compared with those of the control plants, but measurements were not made. This capacity for continued expansion of relatively mature organs is of interest. A similar observation may be inferred from the work of Smith with seedlings of *Pinus radiata* (38). The rapid elongation of bare petioles and the development of narrow wavy laminae of middle leaves of one of the cauliflower plants appeared identical with the field condition known as " Whiptail " which has already been reported to respond to dressings of molybdenum (6), (7). Unpublished observations by one of us (E. J. H.) show that death or rather lack of a growing point is also frequently associated with plants affected with " Whiptail." The narrowing of middle leaves of savoy cabbage plants was again suggestive of the same type of response. Chemical data obtained from field specimens (D.J.D.N. unpublished) suggest that molybdenum deficiency symptoms of " Whiptail " may be possibly induced by excess of manganese. This suggestion would offer a partial explanation of the beneficial effects of liming on " Whiptail " and other cases of molybdenum deficiency. The observations noted above in which symptons resembling some of those induced by manganese toxity were seen when molybdenum was omitted are of interest in relation to the work of Millikan (39) in which extra molybdenum has been found to alleviate symptoms of manganese toxity. The inter-relation implied between manganese and molybdenum will require further investigation.

The difference in nitrate contents of the leaf extracts from molybdenum deficient and normal plants was consistent with the trend in the osmotic pressures of the stomatal guard cells and supports the view that molybdenum is involved in the nitrogen metabolism of higher plants. It is possible that some step in the reduction of nitrates is inhibited in the absence of molybdenum. The work of Bortels (29), (30) and of Horner et al. (31) with nitrogen-fixing organisms, also implies a relation between nitrogen metabolism and molybdenum, as does the differential response of *Aspergillus niger* to ammonium

and nitrate forms of nitrogen when molybdenum is withheld from the nutrient (33), (34). The results obtained on nitrogen fixation in lucerne by Jensen and Betty (32) and the fact that symptoms of molybdenum shortage in leguminous pasture plants (12) may resemble nitrogen deficiency is additional support for this view.

SUMMARY.

1. A technique is described for the study of molybdenum deficiency in plants grown in sand culture and a new method is outlined for the elimination of molybdenum from nutrient reagents.

2. Severe symptoms caused by lack of molybdenum were observed in tomato, cauliflower, savoy cabbage and mustard, and yields of oat straw and grain were also greatly reduced.

3. Injection methods to supply small amounts of molybdenum produced rapid recoveries in deficient plants.

4. There was a marked accumulation of nitrate in the leaf (petiole) tissues and increased osmotic pressures in the stomatal guard cells of cauliflower, mustard and tomato plants from which molybdenum was withheld.

5. Certain symptoms shown by molybdenum deficient cauliflower plants appeared to be identical with the field condition known as " Whiptail."

6. The molybdenum content of molybdenum deficient leaves of tomato varied from 0·18 to 0·23 p.p.m. in dry matter and for mustard 0·6 to 1·0 p.p.m. whereas in those receiving Mo the ranges were from 2·3 to 3·0 p.p.m. and 2·0 to 3·2 p.p.m. respectively.

7. The distribution of deficiency effects in the tomato and in some cruciferous species is discussed in relation to their life histories and the mobility of molybdenum in these plants.

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Fig. 1. Seedling Savoy Cabbage Plants grown without molybdenum.

Fig. 2. Molybdenum deficiency in Cauliflower in sand culture, showing "Whiptail" habit.

Fig. 3. Molybdenum deficient Cauliflower plants, showing death of growing point.

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THE RESOLUTION OF THE FACTORS IN SOIL ACIDITY: THE RELATIVE EFFECTS OF ALUMINIUM AND MANGANESE TOXICITIES ON FARM AND MARKET GARDEN CROPS.

By E. J. HEWITT.

Previous papers in this series (1), (2), (3), indicated that manganese toxicity might account for many of the typical symptoms of soil acidity shown by Brassica crops and by runner beans. It was also found that tolerance to excess manganese may vary between wide limits for different crops and that sugar beet for example may be remarkably tolerant although it is particularly sensitive to soil acidity. In view of several reports in the early literature on problems of soil acidity (4), (5), (6), (7), (8), to the effect that aluminium was the principal injurious factor it was decided to examine the relative effects of excesses of both manganese and aluminium on a range of crop plants grown under varied conditions of calcium supply at two *p*H values of the nutrient solution. Some of the more outstanding results to date are given here.

EXPERIMENTAL.

Materials and Methods.

The technique used in these experiments was essentially similar to that of the previous years but the sand was leached for five days with cold 2% hydrochloric acid to remove the sparingly soluble calcium compounds present. The acid sand was then rinsed with water and appropriate nutrient solution to remove free and exchangeable acid. Appreciable amounts of the latter were found to be present after leaching as was also observed by Arnon and Grossenbacher (9). Sand treated in this manner was used for 'calcium omitted' treatments and for low and high levels of soluble calcium. Calcium was also given in the form of calcium carbonate mixed in the sand at the rate of 10 g. per pot (approximately equivalent to 1 ton per acre).

The nutrient solutions used in the principal experiments had the composition given in Table 1 below. These replaced other solutions in which

TABLE I.

Composition of Basal Nutrient Solutions as Milligramme Equivalents per Litre (meq/L).

Salt	Omitting calcium	Low calcium	High calcium
KNO_3	3·33	3·33	3·33
$NaNO_3$	8·0	7·5	—
$Ca(NO_3)_2$	—	0·5	8·0
NaH_2PO_4 (as PO_4''')	2·0	2·0	2·0
$MgSO_4$	3·0	3·0	3·0

25% and 10% of the total nitrogen supply was given as ammonium and urea nitrogen respectively. Use of these earlier solutions was discontinued when

unexpected symptoms of calcium deficiency were induced in sugar beet and marrowstem kale. The additional manganese and aluminium sulphate treatments comprised two levels of 1·5 and 3 meq/L. (milli-equivalents per litre) of manganese and two levels of 3 and 6 meq/L. of aluminium respectively and a combined treatment of 1·5 meq/L. of manganese with 3·0 meq/L. of aluminium. The manganese levels were raised to 3·0 and 6·0 meq/L. for sugar beet, whilst in the combined treatment they remained as for the other crops. The two pH values of 3·5—4·0 and 5·5—6·0 were produced by addition of sulphuric acid. Rain water was used for all omitting and low calcium treatments and where calcium carbonate was mixed with the sand. Tap water was used later in the season for the high calcium treatments.

Iron and other micro-nutrient elements were supplied as stated in previous papers (2), (3).

The crops grown included sugar beet, potato, cauliflower, marrowstem kale, swede, barley and oat, and the actual basal treatments given, each with and without the manganese and aluminium supplements, are shown in Table II.

TABLE II.

Crops Grown and Basal Treatments Given.

Crop	Basal Treatments
Sugar Beet	Omitting calcium; high soluble calcium, and calcium carbonate in sand with no soluble calcium in nutrient solution.
Cauliflower	Initially as for sugar beet and restarted with low soluble calcium in place of omitting calcium treatment.
Marrowstem Kale	As for cauliflower.
Swede	As for later experiment with cauliflower and kale.
Potato	As for cauliflower but low calcium level reduced to nil in second experiment after 3 weeks and additional experiment with low potassium supply in addition to low calcium level.
Barley	Omitting, low and high soluble calcium treatments each in the absence and presence of calcium carbonate in the sand.
Oat	As for later experiments with cauliflower and kale.

RESULTS.

Visual data.

The visual observations are either detailed in the appendix to this paper or confirmed those already described in previous papers (3), (10), and only the principal results are given here. It was soon evident that the different crop plants varied greatly in their comparative responses to manganese and aluminium toxicity.

Sugar beet proved to be relatively susceptible to excess aluminium; particularly so when sown directly in the sand. The injurious effects were much greater on *early seedling growth* than in older plants, with the result that transplanted seedlings managed to recover whilst those raised directly from seed made little growth and remained " stationary " or died out. The roots in particular showed severe damage and were stunted and brown or killed, whilst foliage was a dull dark green with some scorching, and was

suggestive of phosphorus deficiency. It was also found that sugar beet, either sown or transplanted was relatively much less susceptible to excess manganese than to aluminium whether considered on an equivalent or on a weight for weight basis. Visual symptoms of maganese toxicity were however induced at the highest level of manganese. They appeared as pronounced intervenal yellowish mottling of the older leaves, followed by necrosis and scorching. These symptoms became most severe and persisted longest in the plants given extra calcium carbonate in the sand.

Severe symptoms of calcium deficiency (10) were produced in plants of the omitting calcium series in three weeks from the beginning of the experiment. The combination of excess aluminium and lack of calcium was particularly injurious and caused complete failure within a few weeks when seeds were sown directly, whilst transplanted seedlings made practically no growth. Symptoms of calcium deficiency also developed by mid August in many plants grown with calcium carbonate as a source of calcium, and were rather more pronounced in the presence of additional aluminium. Sugar beet were unique in these experiments in their failure to obtain sufficient calcium from the calcium carbonate admixed in the sand. The effects of aluminium and manganese toxicities and of calcium deficiency are shown in the plate (Fig. 1).

Brassica crops were severely damaged by a much lower concentration of manganese than that required to produce an effect on sugar beet. Moreover the typical effects of root damage from aluminium seen in that crop were not observed, and the Brassicae appeared on the whole somewhat indifferent to the concentrations of aluminium used except for a slight suggestion of phosphate deficiency in the swede. The symptoms of manganese toxicity in cauliflower have already been described in detail (2). (3), and those in kale and swede were closely analogous except that mottling and paling of leaf margins were more noticeable. Severe symptoms of calcium deficiency (3), and death of the plants, occurred in a few weeks in the omitting calcium treatments. The typical symptoms of central chlorotic mottling, necrosis, tip hooking and leaf wilting symptoms were not produced in the plants given calcium as the carbonate when nitrogen was given as nitrate. The swedes grown with the low calcium level showed no signs of calcium deficiency and those given the basal treatment only were similar in appearance to those given the high calcium level or calcium carbonate. Manganese toxicity in kale is shown in Fig. 2.

Barley and oat were both damaged by excess of aluminium ; the former was particularly sensitive and most seedlings were killed by the higher concentration. Oat was more tolerant and the difference was reflected in the relative degree of root damage shown by these two crops. Barley failed to tiller and remained severely stunted ; the roots were dwarfed, contorted and enlarged at the tips (Fig. 4). The foliage was dull blue-green and later tinted with red or purple as in acute phosphate deficiency. Oat resembled barley in both the stunting and lack of tillering but not in root or foliage effects ; whilst premature ear formation in oat was contrary to the usual effects of phosphate deficiency. Both crops appeared rather more tolerant to excess of manganese than of aluminium but oat was particularly so whilst barley was still readily injured (3) especially in the absence of a sufficient concentration of soluble calcium compounds. Manganese toxicity produced dark brown necrotic spotting in the foliage of barley and accentuated death of the growing point in the absence of calcium. In oat the symptoms were yellowish intervenal blotching and irregular mottling. Calcium deficiency appeared in the barley when no calcium was given and was accentuated by extra manganese. No symptoms

of lack of calcium appeared in the other treatments including those with calcium carbonate only.

Potato appeared to be tolerant of the concentrations of excess aluminium given except that marked sypmtoms of phosphate deficiency were induced later in the experiment. This crop was however more sensitive to manganese toxicity and was in this respect intermediate between the Brassicae and barley on one side and oat and sugar beet on the other. The symptoms have already been described (3). Calcium deficiency produced more drastic effects than any other treatment (3) and sprouted tubers set in sand in the complete absence of any calcium supply failed to develop shoots (20). The growing point of each shoot was killed due to breakdown of the shoot just behind this point. (Fig. 3). Root systems however appeared to be normal. Sprouted tubers set in sand given a low calcium level were able to produce shoots the foliage of which showed symptoms of calcium deficiency at a later date. Tubers set in sand with calcium carbonate only, or in unleached sand (containing 30 p.p.m. of Ca as sparingly soluble compounds) with no extra soluble calcium compounds also produced shoots. No symptoms of calcium deficiency appeared in the presence of the calcium carbonate, but were produced later in plants grown in unleached sand without extra calcium, and particularly when part of the nitrogen supply was given as ammonium sulphate.

Potatoes grown with only 0·2 meq/L. of potassium showed typical acute symptoms of lack of this element, whilst in others given excess manganese as well, these symptoms were suppressed and in place of the typical " rust spot " symptoms, blackening occurred *in the veins* on the under surface of the older leaves, black lesions were produced on the stems, and slight chlorotic mottling suggestive of iron deficiency appeared in the younger leaves as noted in 1946 (3). When both calcium and potassium were deficient, excess manganese produced the central necrosis symptoms and blackening of the midrib and major veins of the upper leaf surfaces as noted previously (3).

Interrelationship of Ca, Mn, Al and pH.

The protective action of soluble calcium compounds against the effects of excess manganese has been noted in earlier papers (1), (2), (3), and was again confirmed in these experiments. Calcium carbonate however did not appear to afford such protection and symptoms of manganese toxicity were often similar in severity in both the low calcium and in calcium as calcium carbonate series. Complete omission of calcium generally resulted in severe symptoms of, and death from calcium deficiency before effects of excess manganese were produced. The effects of calcium compounds on aluminium toxicity were in marked contrast to those noted for manganese above. Calcium carbonate greatly reduced the injury from excess aluminium in barley and oats, as shown in Fig. 4, and in sugar beet, more particularly in the early stages. Later, however, in sugar beet a rosette habit, leaf scorching and symptoms of lack of calcium developed. The cereals grown in the presence of excess aluminium maintained better growth throughout the season when calcium carbonate was present but foliage of barley was pale and still showed slight purpling. Transplanted sugar beet on the other hand which also made a better start with calcium given as the carbonate were ultimately inferior in growth to those given a high calcium level in soluble form and these made considerable recovery in the presence of initially damaging concentrations of aluminium sulphate.

The effects of manganese toxicity were greatly accentuated in swede by the reduced *p*H as noted previously for mustard (3) and also by the simultaneous

presence of excess of aluminium, particularly in the low calcium series. It was found by leaching the sand with rain water, that the extra aluminium had produced a marked drop in *p*H to about 4·5 as compared with the basal or high manganese treatments only, which were at 6·5—7. The effect of excess aluminium on manganese toxicity symptoms was less obvious for the other crops but similar indications were obtained with sugar beet, kale and potato.

Tissue Test Data.

Tissue tests were made at intervals during the season on all crops used in these experiments. The protective effect of high levels of calcium in soluble form was again found to be paralleled by reduction in the accumulation of manganese in the tissues as noted in 1945 and 1946 (2), (3). (See tables of tissue test data). Plants given calcium as carbonate contained high concentrations of manganese which were considerably greater than in those given a high level of calcium in soluble form, but usually slightly less than those given a low soluble calcium treatment. (Tables 3, 6, 7, 8). The effect of increased soluble calcium on manganese accumulation by sugar beet (Table 5) was less marked than for the other crops studied and this result agreed with previous unpublished findings ; a similar effect was noted in oat (Table 4). Calcium carbonate moreover seemed to allow at least the same or even greater accumulation of manganese in sugar beet than omission of calcium and this agreed with the severity of manganese toxicity produced in the plants given calcium carbonate. Although much manganese was readily extracted from the petioles still higher concentrations were found in root extracts (Tables 3, 4, 5, 7).

The presence of aluminium sometimes increased the accumulation of manganese as for example in potato and swede (Tables 7, 8). Cereals and sugar beet (Tables 3, 4, 5), did not accumulate manganese so readily as the Brassicae or the potato (Tables 6, 7, 8).

Only very small amounts of aluminium could be extracted from the foliage of treated plants but ten to twenty times greater concentrations were generally found in the washed roots of barley, oat, kale and swede (Tables 3, 4, 6, 7). The presence of aluminium in the nutrient depressed the extractable phosphate in both foliage and root. Far greater concentrations of aluminium were obtained from root extracts of the cereals (Tables 3, 4) than of sugar beet, kale and swede (Tables 5, 6, 7).

Potassium deficiency in the presence of excess of manganese resulted in high concentrations of manganese in potato petioles (Table 8) and potassium appeared as important as calcium in preventing manganese accumulation in toxic amounts in this plant.

DISCUSSION.

These experiments have shown that both manganese and aluminium toxicities may be involved in the injury to crops growing in acid soils. The most outstanding feature of the results was the differential tolerance of the several crops examined to toxic concentrations of manganese or aluminium. Susceptibility of a particular crop plant to manganese toxicity was not necessarily associated with similar sensitivity to aluminium and the converse was equally true. It was noted in an earlier paper in this series (3) that sugar beet was remarkably tolerant of high concentrations of manganese in spite of its liability to fail on even moderately acid soils. These observations can be explained by the fact that sugar beet has now been shown to be highly

TABLE III.

TISSUE TEST DATA FOR BARLEY (CONCENTRATIONS AS PARTS PER MILLION). SOWN 24/7/47.

Sampled	Test for	Omitting Calcium						Low Calcium						Normal Calcium					
		No $CaCO_3$			Extra $CaCO_3$			No $CaCO_3$			Extra $CaCO_3$			No $CaCO_3$			Extra $CaCO_3$		
		Basal	+Mn	+ Al	Basal	+Mn	+ Al	Basal	+Mn	+ Al	Basal	+Mn	+ Al	Basal	+Mn	+ Al	Basal	+Mn	+ Al
7/747	Ca in Stem	25	20	0	0	20	25	25	20	0	0	0	0	20	20	150	25	75	20
	,, ,, Root	500	500	—	200	—	375	50	250	100	100	125	175	450	400	—	500	400	—
	Mn in Stem	0·5	6·0	0·2	0·5	4·0	0·2	0·5	6·0	0·	0	3·0	1·0	0·5	2·5	0	0·2	3·0	0·5
	,, ,, Root	3·0	70·0	—	1·0	16·0	—	0·5	100	—	1·0	48·0	—	1·0	50·0	—	1·0	72·0	—
	Al in Stem	0·4	0·5	0·5	0·2	0·2	0·5	0·2	0·1	0·2	0	0	0	0·4	0·2	0·2	·02	·02	0·2
	,, ,, Root	0·8	—	4·0	1·8	—	7·0	0·8	—	5·0	0·8	—	2·5	1·5	—	15·0	1·5	—	4·0
	PO_4 in Stem	165	90	50	55	50	20	100	40	20	50	40	10	50	25	0	50	20	20
	,, ,, Root	100	90	10	30	90	10	15	120	15	20	20	15	30	40	8	35	35	
8/8/47	Ca in Stem	0	10	0	0	0	16	0	0	0	0	0	0	less than 10					
	Mn ,, Stem	0·2	7·0	0·2	0·2	5·0	0·2	0·5	7·0	0·2	0·2	6·0	0·2	0·2	5·0	0	0·2	2·5	0
	Al ,, Stem	0·15	—	0·15	0·1	0·1	0·15	0·1	0·1	0·1	0·1	0·1	0·1	0·05	0·1	0·05	0·05	0·05	0·05
	PO_4 ,, Stem	140	80	15	20	15	5	30	45	10	45	20	5	30	10	10	10	12	10
14/6/47 Separate Experiment Sown 7/5/47	Al in Stem						0·5						0·5						0·5
	,, ,, Root						7·0						7·0						5·0
	PO_4 in Leaf						8						30						30
	,, ,, Root						10						10						10

Mn at 1·5 meq/L. Al at 3·0 meq/L. p_H 5·5—6·0

TABLE IV.

TISSUE TEST DATA FOR OAT. SOWN 27/5/47.

Sampled	Test for	Low Calcium			Normal Calcium			Calcium as $CaCO_3$ No soluble Calcium		
		Basal	+Mn	+ Al	Basal	+Mn	+ Al	Basal	+Mn	+ Al
11/6/47	Ca in Stem	5	5	—	50	50	—	25	25	—
	Mn ,, Stem	0·5	9·0	—	1·0	6·0	—	0·5	4·0	—
14/7/47	Ca in Stem	5	5	150	175	100	0	10	5	5
	,, ,, Root	5	50	50	200	400	10	200	300	50
	Mn in Stem	0·5	7·0	0	0·5	6·0	0·5	0·5	5·5	0
	,, ,, Root	0·5	42	0·2	0·5	64	0·2	0·2	112	0·2
	Al in Stem	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·8	0·5
	,, ,, Root	0·2	0·5	1·5	0·8	1·0	5·0	0·5	0·8	10·0
	PO_4 in Stem	45	30	7	20	10	15	40	12	10
	,, ,, Root	5	20	10	7	25	—	5	60	5

11/6/47 Mn at 3·0 meq/L. 14/7/47 Mn at 1·5 meq/L. Al at 3·0 meq/L. *p*H 5·5—6·0.

TABLE V.

Tissue Test Data for Sugar Beet.

Sampled	Test for	Omitting Calcium			Normal Calcium			Calcium as $CaCO_3$		
		Basal	+Mn	+ Al	Basal	+Mn	+ Al	Basal	+Mn	+ Al
10/7/47	Ca in Petiole	0	0	—	0	0	—	0	0	—
Seedlings	,, ,, Root	0	10	—	10	10	—	5	0	—
sown	Mn in Petiole	0·2	9·0	—	0·5	8·0	—	0·5	9·0	—
direct in	,, ,, Root	1·0	27·0	—	2·0	9·0	—	1·0	27·0	—
sand on	PO_4 in Petiole	5·0	30	—	10	5	—	25	35	—
4/5/47	,, ,, Root	100	85	—	50	35	—	120	85	—
16/7/47	Ca in Petiole	0	0	—	15	0	0	0	0	0
Adult	Mn ,, Petiole	0·2	10·0	—	0·2	8·0	0·2	0·2	10·0	0·2
foliage of	Al ,, Petiole	0·05	0·05	—	0·05	0·05	0·1	0	0·05	0
plants trans-	PO_4 ,, Petiole	15	20	—	15	5	3	15	10	3
planted on 29/4/47										
11/9/47	Ca in Petiole	0	0	0	0	0	0	0	0	0
(trans-	Mn ,, Petiole	0·2	9·0	—	0·5	2·5	0·5	0·2	10·0	0·2
planted	Al ,, Petiole	0	0	·005	0	0	0	0	0	0
plants)	PO_4 ,, Petiole	45	80	15	45	5	5	35	40	10
10/10/47	Ca in Petiole	0	0	0	0	0	0	0	0	0
(trans-	Mn ,, Petiole	0·2	7·0	0·2	0·5	3·5	0·2	0·2	10·0	0·2
planted	Al ,, Petiole	0	0	0	0	0	0	0	0	0
plants)	PO_4 ,, Petiole	30	40	15	15	5	5	20	60	10
23/10/47	Ca in Root	0	0	0	0	0	0	0	0	0
(trans-	Mn ,, Root	0·2	20·0	1·5	2·5	6·5	0·5	0·2	23·0	0·5
planted	Al ,, Root	0	0	0·1	0	0	0·05	0	0	0·05
plants)	PO_4 ,, Root	50	35	10	15	10	3	50	25	5

Mn at 3 meq/L. Al at 3 meq/L. *p*H 5·5—6·0.

TABLE VI.

Tissue Test Data for Cauliflower and Marrowstem Kale.

Sampled	Test for	Omitting Calcium			Low Calcium			Normal Calcium			Calcium as $CaCO_3$		
		Basal	+Mn	+ Al	Basal	+Mn	+ Al	Basal	+Mn	+ Al	Basal	+Mn	+ Al
Cauliflower	Ca in Petiole	0	0	—				50	50	60	10	10	30
16/5/47	Mn ,, Petiole	0	18	—				0·5	6·0	0·5	0	4	0
(1st Experiment	Al ,, Petiole				All Below 0·05								
Transplanted 14/5/47	PO_4 ,, Petiole	15	—	—				15	20	3	20	20	10
20/8/47	Ca in Petiole				0	100	25	25	100	75	40	50	40
(2nd Experiment	Mn ,, Petiole				0·5	36·0	1·0	0·2	1·0	0·2	1·0	18·0	1·0
Transplanted 7/7/47)	Al ,, Petiole							All Below 0·05					
	PO_4 ,, Petiole				45	105	15	20	12	10	40	65	10
Kale	Ca in Petiole	—	—	—				100	100	100	75	50	75
30/6/47	Mn ,, Petiole	—	—	—				0·5	6·0	0·2	0·5	26·0	0·2
(1st Experiment	PO_4 ,, Petiole	—	—	—				25	45	15	40	45	15
Transplanted 30/4/47)	Al ,, Petiole	—	—	—				0	0·05	0	0	0·05	0·1
	Al ,, Root	—	—	—				0·1	0·2	0·8	0·1	0·1	1·0
20/8/47	Ca ,, Petiole				100	25	10	125	140	75	140	25	30
(2nd Experiment	Mn ,, Petiole				0·5	14·0	0·5	0·5	2·5	—	1·0	12·0	0·5
Transplanted 10/7/47	PO_4 ,, Petiole				30	35	20	15	5	10	15	20	10

Mn at 1·5 meq/L. Al at 3·0 meq/L. *p*H 3·5—4·0.

TABLE VII.

TISSUE TEST DATA FOR SWEDE. SOWN 17/6/47

Sampled	Test for	pH 5·5—6·0												pH 3·5—4·0											
		Low Calcium				Normal Calcium				Calcium as $CaCO_3$				Low Calcium				Normal Calcium				Calcium as $CaCO_3$			
		Basal	+ Mn_1	+ Mn_2	+ Mn & Al	Basal	+ Mn_1	+ Mn_2	+ Mn & Al	Basal	+ Mn_1	+ Mn_2	+ Mn & Al	Basal	+ Mn_1	+ Mn_2	+ Mn & Al	Basal	+ Mn_1	+ Mn_2	Mn & Al	Basal	+ Mn_1	+ Mn_2	Mn & Al
23/7/47	Ca in Petiole	10	10	10	5	0	10	10	125	10	10	10	10	5	10	100	0	30	100	30	75	10	75	100	100
	,, ,, Hypocotyl	50	25	—	5	100	10	—	—	100	5	—	10	50	10	—	—	75	—	—	—	75	—	—	—
	Mn ,, Petiole	0·2	3·0	11·0	5·5	0	1·5	2·0	1·5	0	0·75	3·0	2·5	0·2	6·0	24·0	9·0	0·2	2·0	2·5	1·5	0·2	2·5	4·5	3·5
	,, ,, Hypocotyl	0·2	5·0	14·0	8·0	0·2	2·0	5·5	2·0	0	2·0	5·5	5·5	0·2	12·0	21·0	11·0	0·2	2·5	6·0	4·0	0·5	7·0	10·0	5·0
	PO_4 in Petiole	10	10	10	7	5	5	below 5	below 5	15	5	5	5	15	15	50	30	5	5	15	15	15	15	10	20
	,, ,, Hypocotyl	65	25	55	15	30	45	—	—	45	20	15	20	70	50	—	—	30	25	35	—	60	55	—	—
20/8/47	Ca in Petiole	10	25	†	25	100	100	75	30	25	30	25	100	10	10	†	0	200	25	25	100	150	25	30	175
	Mn in Petiole	0	9·0	†	21·0	0	1·5	2·5	1·0	0·2	6·0	30·0	14·0	0	12·0	†	14·0	0	1·0	1·5	1·5	—	7·0	27·0	12·0
	PO_4 in Petiole	15	15	†	7	5	5	5	3	20	15	50	20	15	50	†	50	—	3	3	3	15	15	70	10
16/9/47	Ca in Petiole	15	25	†	†	100	50	25	45	10	30	†	30	10	50	†	†	30	200	30	25	10	25	†	25
	Mn in Petiole	0	20·0	†	†	0·2	1·5	4·0	1·0	1·0	9·0	†	7·0	0	22·5	†	†	0·2	1·0	3·0	1·0	1·0	18·0	†	18·0
	PO_4 in Petiole	200	240	†	†	15	3	3	0	30	20	†	15	200	320	†	†	15	10	7	0	20	120	†	15
13/10/47	Ca in Roots	15	100	†	†	100	75	75	75	20	125	†	—	15	†	†	†	100	100	100	110	75	100	†	†
	Mn in Roots	0	60·0	†	†	0	1·0	5·0	2·0	1·0	54·0	†	25·0	0·2	†	†	†	0	1·0	3·0	1·5	1·0	18·0	†	†
	PO_4 in Roots	110	80	†	†	10	10	15	5	25	130	†	—	15	†	†	†	15	10	10	0	65	70	†	†

† Dead at time of sampling. Mn at 1·5 and 3·0 meq/L.
Mn & Al at 1·5 and 3·0 meq/L. respectively.

TABLE VIII.

TISSUE TEST DATA FOR POTATO TUBERS SET ON 7/6/47.

Sampled	Test for	*p*H 5·5—6·0												*p*H 3·5—4·0									
		Low Calcium			Normal Calcium			Calcium as $CaCO_3$			Low Potassium			Low Calcium			Normal Calcium			Calcium as $CaCO_3$			Low Potassium		
		Basal	+ Mn	+ Mn & Al	Basal	+ Mn	+ Mn & Al	Basal	+ Mn	+ Mn & Al	Basal	+ Mn	+ Mn & Al	Basal	+ Mn	+ Mn & Al	Basal	+ Mn	+ Mn & Al	Basal	+ Mn	+ Mn & Al	Basal	+ Mn	+ Mn & Al
18/7/47	K in Petiole	—	—	—	600	300	175	700	350	175	10	35	110	—	—	—	650	350	300	500	275	300	10	30	70
	Ca ,, Petiole	—	—	—	50	130	65	5	5	5	—	—	—	—	—	—	80	130	20	5	5	5	—	—	—
	Mn ,, Petiole	—	—	—	0·2	20·0	25·5	0·2	17·0	17·5	0·2	17·0	27·0	—	—	—	0·2	7·5	17·0	0·2	9·0	18·0	1·5	14·0	25·5
26/8/47	K in Petiole	175	125	250	80	125	200	150	200	300	50	250	250	300	300	300	150	250	250	250	300	400	50	175	250
	Ca ,, Petiole	0	0	0	50	100	200	5	20	90	250	250	200	5	0	0	75	75	75	0	0	125	250	150	150
	Mn ,, Petiole	1·0	21·0	30·0	0·5	12·0	24·0	1·0	30·0	40·0	1·5	40·0	40·0	1·0	28·0	32·0	0·5	8·0	18·0	0·5	10·0	36·0	—	36	56
	PO_4 ,, Petiole	15	20	10	3	5	7	10	10	7	180	65	110	45	50	30	5	5	8	10	10	7	200	180	150

Mn at 1·5 meq/L. Al at 3·0 meq/L.

susceptible to aluminium toxicity. Aluminium toxicity moreover induces the effects most frequently encountered when sugar beet fail in acid soils. (11), namely a "stationary" and intensely dwarfed development soon after germination, dull blue-green foliage and poor or abnormal root systems. Symptoms of manganese toxicity are less frequent in the field but are also clearly recognisable, usually in circumstances of inadequate liming of a formerly highly acid soil. The tendency for roots of sugar beet in acid soils to trail horizontally in the surface layers still remains to be explained.

Barley and oat were both injured by excess of aluminium but barley was particularly sensitive and showed the symptoms of root injury also produced in sugar beet, and of phosphate deficiency in the foliage usually seen under acid conditions. Oat was also much less sensitive to manganese toxicity than barley and these differences may largely account for the success of oats when barley fails. The symptoms of root injury and associated aluminium accumulation and low concentration of soluble phosphate agree with the findings of other workers (12), (13), (14). The observations of Abbot *et al* (6), Mann (15) and Sorauer, (16), (p. 136) also suggest the view that aluminium toxicity is the most frequent cause of failure in cereals on acid soils. The symptoms seen in oat given excess manganese resembled those sometimes found under acid conditions, whilst comparison of the symptoms reported by Pierre (17) and by Mann and Barnes (18) for barley in some acid soils, with those produced by manganese toxicity in these experiments suggests that this factor may also on occasion be another cause of failure in barley.

Brassica crops and potato were in marked contrast to the beet and cereals and were not appreciably injured by the high aluminium concentrations. The Brassicae were particularly sensitive to manganese toxicity as found previously (3). It was of interest to note that while hungry gap kale used in 1946 was shown to be an exception to this rule (3), the marrowstem variety was among the most sensitive of all to excess manganese. Russell (19) listed kale as among the most sensitive of crops to soil acidity. The potato was intermediate between the Brassicae and oat, and sugar beet the least sensitive of all to manganese toxicity. It was found that the effects of manganese toxicity in potato were modified according as to whether calcium, or potassium, or both were deficient and also that the usual symptoms of potassium deficiency were suppressed and substituted by others when excess manganese levels were present in the nutrient solution. The most frequent symptoms seen in potatoes in acid soils however were reproduced by calcium deficiency and this may cause failures even at the earliest stages of growth after setting the tubers (20). Although calcium deficiency is the usual cause of failure in potatoes (20), other symptoms due to manganese toxicity are also well known and of these, the stem speckling or lesions already described are most frequent. Similar symptoms have been reported recently for potatoes suffering from acidity in some American soils (21).

The protective effect of increased concentrations of soluble calcium compounds for manganese toxicity was again fully confirmed. It was noted however, in these (and other unpublished observations) that the accumulation of soluble manganese in the tissues was less restricted for sugar beet by increased calcium level than for most crops. When calcium was supplied as calcium carbonate, it was found that the protective effect against manganese toxicity and accumulation was apparently much less but this source of calcium was more effective in preventing injury by excess aluminium, particularly in the cereals where soluble calcium compounds seemed of relatively little value in

this respect. This difference may have been partly due to the effect of calcium carbonate on the *p*H of the medium since the dissociation of the aluminium compounds would be most likely greatly reduced by the presence of the free calcium carbonate in the sand. Hale and Heintze (22) and Hale *et al.* (23) have found that sugar beet may be injured by manganese toxicity and yet have an apparently normal calcium status with abnormally high manganese contents; this is compatible with the observations made here that calcium supply in sand culture has less effect on the accumulation of manganese by sugar beet than by many other crops.

SUMMARY.

1. Sand culture experiments were made with sugar beet, cauliflower, marrowstem kale, swede, barley, oat and potato in which the effects of excess manganese and aluminium at different calcium concentrations were examined.

2. Sugar beet and barley were highly susceptible to injury by aluminium toxicity and oat was rather less sensitive. Brassica crops and potato were relatively tolerant to concentrations of aluminium sulphate that caused severe damage to the others.

3. The symptoms of aluminium injury were most marked during early growth, and particularly in the roots which were characteristically distorted. Foliage symptoms frequently resembled those of phosphate deficiency and this was so in sugar beet, cereals (and in potato late in the experiments).

4. The damage caused to cereals by aluminium toxicity was greatly reduced by admixture of 0·1% by weight of $CaCO_3$ in the sand, whilst increased calcium supply in soluble form had much less effect. This effect of $CaCO_3$ was also observed in sugar beet but was less marked in older plants which ultimately grew more vigorously when calcium was given in soluble form.

5. Brassica crops were all highly susceptible to manganese toxicity, followed in order of increasing tolerance by barley, potato, oat and sugar beet. The latter was found to be unusually tolerant, but characteristic symptoms were induced at manganese concentrations about four times those causing severe damage to kale.

6. Foliage symptoms of manganese toxicity in Brassicae were alike in many respects and in all the crops studied they were distinct from effects caused by iron deficiency, which did not appear in these experiments.

7. Increased concentrations of soluble calcium compounds greatly reduced the severity of the symptoms in cereals, Brassicae and potato, thus confirming previous findings. $CaCO_3$ had little protective effect in most instances and even accentuated the symptoms in sugar beet.

8. Sugar beet differed from the other crops studied in being unable to obtain sufficient calcium for normal growth from calcium carbonate mixed in the sand.

9. Effects produced by excess of aluminium or of manganese, or by lack of calcium were identified with those seen in the crops studied when suffering from soil acidity. The relative importance of each of these factors was found to vary greatly for different crops.

10. Aluminium toxicity was the most readily recognised effect in sugar beet and barley; manganese toxicity accounted for the usual symptoms of injury in Brassicae, whilst calcium deficiency appeared mainly responsible for failures in potatoes. Manganese toxicity produced typical but less common symptoms of soil acidity in sugar beet, potato and oat.

11. Chemical tissue tests revealed high concentrations of manganese

in the leaf and root tissues of plants given an excess of this element. These concentrations were reduced by increased levels of soluble calcium. Appreciable amounts of aluminium were rarely obtained from the leaves of aluminium treated plants but larger quantities were extracted from the roots; such plants usually had a low phosphate status.

APPENDIX.

Description of Visual Symptoms produced by Excess of Manganese or Aluminium.

Sugar Beet.

Manganese toxicity: habit stunted, young leaves erect, older ones more horizontal, narrow, turgid with backward curl; diffuse pale yellowish blotching between major veins becoming bright yellow with necrosis in chlorotic areas and marginal scorching and tearing producing ragged foliage; roots brown but not obviously injured.

Aluminium toxicity: habit severely stunted, seedlings fail to grow soon after germination (about 3rd—4th leaf stage) usually dying out or remaining stationary for several weeks, foliage dark blue-green, dull and lustreless as in phosphate deficiency; root system severely damaged especially at tip with browning and death of lateral roots at time of emergence from tap root Symptoms, especially root damage, particularly severe in absence of calcium and greatly alleviated in early stages by calcium carbonate, but later, in presence of latter, developing into calcium deficiency complicated by dull dark green foliage with brown marginal scorching and stunted rosette habit.

Combined aluminium and manganese: Symptoms of aluminium toxicity.

Marrowstem Kale.

Manganese toxicity: Growth reduced, leaves small; older leaves, margins severe forward cupping with intervenal crinkling; whitish or yellow green marginal paling (rim effect) followed in some leaves by intervenal yellow-green marginal mottling leaves finally scorching at margins with irregular brown intervenal necrotic areas, perforation, severe distortion, and attrition of lamina; black or indigo elongated markings or lesions on lower side of petioles.

Swede.

Manganese toxicity: Cotyledons yellowing with purple tints; seedlings with clearly-marked whitish marginal chlorosis fading later into general mottling; at low calcium levels high concentrations of manganese producing severe leaf distortion and intervenal crinkling and irregular cupping of foliage with irregular yellow or whitish blotching followed by death of plants. Fur further details of manganese toxicity see earlier paper (3).

Combined aluminium and manganese: Symptoms of manganese toxicity only and more severe.

Marrowstem Kale, Cauliflower and Swede.

Aluminium toxicity: Effects only slight; slight dwarfing, foliage somewhat dull dark green; occasional trace purplish tinge in swede and kale as in mild phosphate deficiency.

Combined aluminium and manganese: Symptoms of manganese toxicity only.

Potato.

Aluminium toxicity: Slight stunting, leaves small, foliage lustreless, light green with dull olive green tint followed late in season by scorching and upcurled margins as in phosphate deficiency.

Combined aluminium and manganese: Symptoms of manganese toxicity.

Barley.

Calcium deficiency: Growth stunted, tillering rapidly; whitish lesions near tips of young leaves, wilting and shrivelling, emerging leaves chlorotic white, withering rapidly followed by death of growing point and of plants. Symptoms accentuated by presence of excess manganese.

Aluminium toxicity: Growth dwarfed and severely stunted, only attaining 3–5″ height, tillering absent; leaves erect, narrow and pointed, dull blue-green followed by purpling margins, veins and leaf bases; later dark purple flush and browning and withering from tips; stems becoming dark brown or black; roots stunted, bent irregularly, brown thickened and enlarged at tips; no ear formation, death of plants.

Symptoms not markedly reduced by increased concentration of soluble calcium compounds but almost eliminated by calcium carbonate except for pale dull green foliage with pale purple tinting; roots normal.

Oat.

Manganese toxicity: Growth only slightly reduced, tillering normal; foliage pale; discontinuous, irregular yellowish intervenal blotches becoming orange-yellow; slight scorching of older leaves; foliage faintly stippled by alternate light and darker green areas in parallel lines along leaves.

Aluminium toxicity: Growth dwarfed; height about 12–15″; tillering greatly reduced; leaves small, narrow, erect, dull pale green or blue green, scorching at tips, and browning, no purple tinting; roots slightly stunted and thickened (but injury far less severe than in barley); ear formation premature but very much reduced. Stunting greatly reduced by calcium carbonate and rooting and tillering normal; calcium in soluble form had little effect.

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Fig. 1. Young sugar beet plants. Top left: early stages of manganese toxicity. Bottom left: aluminium toxicity. Right: calcium deficiency.

Fig. 2. Manganese toxicity in marrowstem kale.

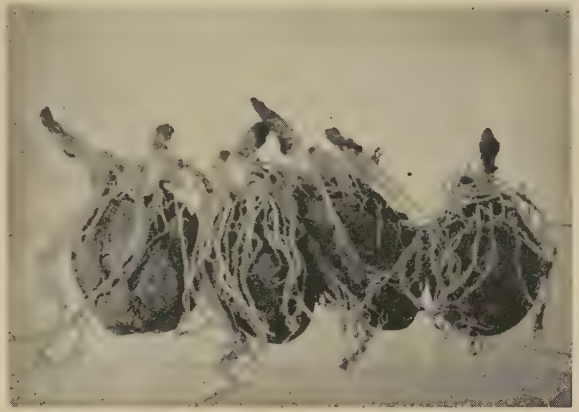


Fig. 3. Effects of severe calcium deficiency on sprouted potato tubers.

Fig. 4. Effects of aluminium toxicity on barley seedlings. Left: with low level of calcium nitrate. Right: with normal level of calcium

SOME EFFECTS OF LIME AND FERTILISERS ON POTATOES ON A STRONGLY ACID SOIL AS DETERMINED BY VISUAL SYMPTOMS AND CHEMICAL TESTS. II.

By W. PLANT, E. J. HEWITT and D. J. D. NICHOLAS.

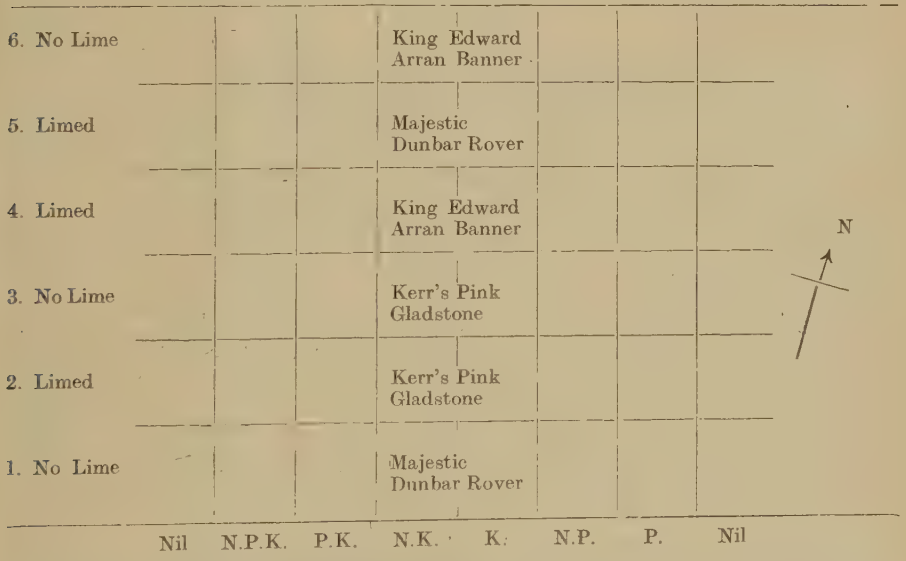
An account has already been given in the Annual Report 1946 (1) of the effects of liming and of various fertiliser treatments, with and without lime, on the incidence of mineral deficiencies and excesses in the potato, variety Majestic, grown on a strongly acid soil reclaimed from heath. During 1947 six potato varieties were grown on part of the same plot in order to determine the differential response in vigour and incidence of mineral deficiencies and excesses.

EXPERIMENTAL.

The layout of the plot, including varieties, liming, fertiliser treatments and rates of application, is shown in Table I.

TABLE I.

Layout of Plot, Varieties, Liming and Fertiliser Treatments.



As the original plots were arranged in ten limed or unlimed strips, and there were six varieties in this experiment to be compared, six consecutive strips were chosen and each subdivided for two varieties. The potatoes were planted on 19/5/47 and the plots were scored for vigour and visual symptoms on 30/7/47 and on 5/9/47. Tissue tests were carried out on 30/7/47 for the variety Majestic and leaf samples for chemical ash analysis were taken at the same time. The growing period was particularly dry, since long periods of drought occurred during the summer.

Fertiliser Treatments (applied Spring 1947).

N = Nitrogen (Sulphate of Ammonia) 3 cwt. per acre.
P = Phosphate (Superphosphate) 5 ,, ,, ,,
K = Potash (Muriate of Potash) $2\frac{1}{2}$,, ,, ,,
Lime = Ground limestone 9 tons to acre applied 1944.

RESULTS.

Table II gives a marking for vigour of haulm for the two scorings, there being an interval of 5 weeks between; and in order to facilitate comparisons the limed and unlimed data for each variety are placed adjacent. As there is no more than 5% difference between the two scorings it has been possible to average the totals from both. The overall responses of the varieties to no lime, lime applications, and the resultant difference between are shown in the following descending order from left to right by the use of Total averages given at the bottom of Table II.

No lime	Majestic	Arran Banner	King Edward	Kerr's Pink	Dunbar Rover	Gladstone
	30	29	29	28	26	19
Lime	Dunbar Rover	Kerr's Pink	Gladstone	King Edward	Arran Banner	Majestic
	47	40	35	35	32	30
Difference (L—N.L.)	Dunbar Rover	Gladstone	Kerr's Pink	King Edward	Arran Banner	Majestic
	21	16	12	4	3	0

Thus where no lime was applied Gladstone gave a lower mark than the other five varieties; on liming, Dunbar Rover, Kerr's Pink and Gladstone responded most whilst the score of the three remaining varieties remained relatively the same. Subtracting the no-lime totals from the lime totals, Dunbar Rover showed the greatest difference, followed by Gladstone and Kerr's Pink and lastly by King Edward, Arran Banner and Majestic, the growth of these three varieties apparently not responding to lime on these plots in 1947.

The response to fertiliser treatment, irrespective of variety, is shown in descending order from left to right by averaging the fertiliser treatment totals in the N.L. and L. columns.

No lime	N.P.K.	P.K.	P.	K.	Nil	Nil	N.P.	N.K.
	32	26	19	18	18	17	17	14
Lime	N.P.K.	P.K.	N.K.	K.	N.P.	P.	Nil	Nil
	39	34	29	29	28	25	18	16

Either with or without lime the N P K and P K treatments were markedly superior to the rest. The least satisfactory treatment with N.L. was N K which scored less than the Nils, whilst on the L strips improvement was shown by K, N K, P and N P.

Dunbar Rover, King Edward, Gladstone and Kerr's Pink responded to K and P alone or in combination on the limed plots. Gladstone, Kerr's Pink and King Edward responded in particular to P alone, whilst Dunbar Rover, Gladstone and Kerr's Pink showed the more striking haulm response to K, P K, and N P K.

Visual Symptoms.

The symptoms either of mineral deficiencies or excesses shown by each variety are tabulated in Table III. There are no outstanding differences in the response shown between varieties except that of degree which is indicated indirectly in Table II, and the main symptoms extracted from the columns

TABLE II.

SCORINGS FOR VIGOUR (MAXIMUM 10).

Scored on 30.7.47	Majestic		Dunbar Rover		Arran Banner		King Edward		Gladstone		Kerr's Pink		Totals	
	N.L.	L.	N.L.	L.	N.L.	L.	N.L.	L.	N.L.	L.	N.L.	L.	N.L.	L.
Nil	4	2	2	3	3	3	3	4	2	2	3	4	17	18
N.P.K.	6	5	5	8	5	6	5	7	5	4	6	4	32	34
P.K.	4	4	4	7	5	5	5	5	4	5	4	5	26	31
N.K.	4	3	1	6	3	4	4	4	1	3	2	4	15	24
K	4	4	3	6	4	4	4	4	2	5	2	6	19	29
N.P.	2	3	2	4	4	5	4	5	2	4	4	5	18	26
P.	4	3	5	3	4	3	3	3	2	7	4	8	22	27
Nil	4	2	4	3	4	2	3	3	2	2	3	2	20	14
Totals	32	26	26	40	32	32	31	35	20	32	28	38	169	203
Scored on 5.9.47.														
Nil	4	3	4	5	2	3	2	3	1	2	4	3	17	19
N.P.K.	6	6	5	9	6	7	5	7	5	8	6	8	33	45
P.K.	5	6	5	7	5	5	5	6	3	7	4	6	27	37
N.K.	4	6	1	8	3	4	4	5	0	6	1	6	13	35
K.	3	5	2	8	3	4	4	4	2	4	3	5	17	30
N.P.	1	4	1	7	3	5	4	4	3	5	4	6	16	31
P.	3	3	4	6	2	3	1	3	2	4	4	4	16	23
Nil	3	2	4	5	2	2	2	3	2	1	3	5	16	18
Totals	29	35	26	55	26	33	27	35	18	37	29	43	155	238
Total averages	30	30	26	47	29	32	29	35	19	35	28	40	162	220
Diff. (L.-N.L.)	0		21		3		4		16		12		58	

are shown on the righthand side of Table III. On the unlimed plots one or more of the deficiencies of N, P, K, Ca, Mg and excess of Mn occurred whilst on the limed plots only deficiencies of N, P, K, Mg were found. The N.L. plots on the second diagnosis showed no Mg deficiency but Mn excess. The symptoms resulting from the soil acidity complex are difficult to diagnose (2) and in this case were more specific at the later date than at the first inspection. Apart from the nil plots which showed the soil to be deficient in P the interactions of the different fertilisers indicated that P K treatment induced

N deficiency; N K and K treatments accentuated P deficiency, and N P and P treatment induced K deficiency. Manganese toxity symptoms were also more marked where K was omitted. On the limed plots in particular, slight Mg deficiency was induced by N P K, P K, N K and K but not by N P or P alone, an observation also made last year at the centre.

Chemical Data.

The data in Table IV concern Majestic growing on the N.L. strip No. 1 and the L. strip No. 5 (see Table I). The full chemistry of the nil plots on the no lime strip show that the status of K and Mg are satisfactory; Ca and P are low and Mn is high, whereas on the limed counterpart, Ca is high and the Mg and Mn are comparatively low. The interactions of the high Ca status on the other nutrients indicate that P and especially Mg levels are depressed in all fertiliser treatments and K materially so in the P and N P treatments whilst the Mn is also reduced but less so on the East side of the plot which probably is a reflection of a soil difference. Other interactions include the depression of P by K manuring and vice versa and the lowering of Mg by K. fertilisers where lime had previously been applied.

Comparison of Visual, Tissue tests and chemical data. Table IV.

So far as deficiencies of K, Mg and P are concerned there is reasonable agreement between all three methods. When the Ca status is low as shown by analysis and tissue tests, deficiency symptoms do not necessarily follow, especially on the Nil plots. Likewise where a high Mn status is shown by chemical methods visual symptoms are not necessarily apparent except where K was omitted from the treatments.

DISCUSSION.

This experiment has corroborated the main findings of the previous year's work (1) and furthermore shown that deficiencies of N, P, K, Ca and Mg and excess Mn effect a range of six potato varieties in varying degree. For instance Gladstone was less tolerant of the acidity complex in so far as growth was concerned than the rest, whilst Dunbar Rover and Kerr's Pink benefited most as a result of liming. The use of an N P K fertiliser appears to be most advisable from the results of this work although even with this treatment magnesium deficiency still remains to be corrected. Similarly, as found in the 1946 experiments, when P or K only were given separately, each induced a deficiency of the other.

In estimating growth responses to lime and fertiliser treatments, the quality of the resultant tuber must be considered and a full account of this aspect of the experiment is discussed elsewhere (see page 233). Successful potato growing involves the integration of many ecological factors of which some still need elucidation as has been pointed out previously (4). Even so, wherever the nutrient problems of the potato require investigations in the field the use of the three methods, visual, tissue tests and full chemical analysis are essentially complementary approaches of great practical use.

SUMMARY.

1. The effects of liming and of various fertiliser treatments, with and without lime, were examined in 1947 on six potato varieties, Majestic, Dunbar Rover, Gladstone, Kerr's Pink, King Edward and Arran Banner, in relation to the incidence of mineral deficiencies and excesses. The site was situated

TABLE III.

OCCURRENCE OF DEFICIENCIES AND EXCESSES DIAGNOSED BY SYMPTOMS ON 30/7/47 AND 5/9/47.*

30/7/47	M.		D.R.		A.B.		K.E.		G.		K. Pink		Main effects	
	N.L.	L.	N.L.	L.	N.L.	L.	N.L.	L.	N.L.	L.	N.L.	L.	N.L.	L.
Nil	P	P	P	P	P	P	P	P	P	P	P	P	P	P
N.P.K.	Ca	Mg	Mg	Mg	Mg	Mg	Ca Mg	Mg	Mg	Mg	Mg	Mg	Mg	Mg
P.K.	Ca	N Mg	N Mg	Mg	Mg	N Mg	Ca N	N Mg	N Mg	N Mg	N Mg	N Mg	N Mg	N Mg
N.K.	P Ca	P	Ca	P Mg	P	P Mg	P Ca	P Mg	Ca Mn+	P Mg	Ca Mn+	P Mg	P Ca Mg	P, Mg
K.	P	P Mg	P	Mg	P Mg	P Mg	P Ca Mg	P Mg	P Mg	N Mg	P Ca Mg	Mg	P Mg	P Mg
N.P.	K Ca Mn+	K	K	K	K Mn+	K	Ca Mg Mn+	K	Ca Mn+	K	K Mn+	K	K Ca Mn+	K
P.	Ca Mn+	K	—	K	K Ca Mn+	K	Ca K Mg	K	K Ca Mg	K	K Mn+	K	K Ca Mn+	K
Nil	Mn+	P	—	P	P Mg	P	P	P	Ca	P	P	P	P	P
5/9/47														
Nil	P Mn+	P	P Mn+	P	P Mn+	K P	P Mn+	P	P	P	P Mg	K	P Mn+	P
N.P.K.	Ca	—	Mn+		—	—	Ca	—	Mn+	—	P	Mg	—	—
P.K.	—	N	N	N Mg	N Mn+	N Mg	N	N Mg	N Mn+	N	N Mn+	N Mg	N Mn+	N Mg
N.K.	P Ca Mn+	P	—	Mg	P Mn+	P Mg	P	P	—	Mg	P Mn+	P Mg	P Mn+	P Mg
K.	P Mn+	P Mg	P Mn+	Mg	P Mn+	P Mg	P	P	Mn+	Mg	P Mn+	Mg	P Mn+	P Mg
N.P.	K Mn+	K	K Mn+	K	K Mn+	K	K Mn+	K	K Mn+	K	K Mn+	K	K Mn+	K
P.	K Ca Mn+	K	Mn+	K	K Mn+	K	K Mn+	K	Ca Mn+	K	K Mn+	K	K Mn+	K
Nil	Mn+	P	Mn+	K	P Mn+	P	P	P	Mn+	—	P Mn+	K	P Mn+	P

* Mn+ = excess of Mn.
N.P.K. Ca. Mg. = deficiency of these elements.

TABLE IV.

SHOWING THE RELATION BETWEEN VIGOUR MARKING, VISUAL SYMPTOMS, FULL CHEMICAL TISSUE TEST DATA FOR K, Mg, Ca, P, Mn, IN VARIETY MAJESTIC.

Manurial treatment	Crop vigour max. 10	Visual Symptoms	Full Chemical Data					Tissue Test Data*				
			as % Dry Matter				p.p.m.					
			K_2O	MgO	CaO	P_2O_5	Mn	K	Mg	Ca	PO_4	Mn
1. Nil no lime	4	—P	2·91	0·70	1·09	0·40	422	M+	H	L+	M	H+++
2. N.P.K. ,,	6	—Ca	4·90	0·56	0·83	0·58	536	H	H—	L+	M—	H+++
3. P.K. ,,	4	—Ca	4·10	0·36	0·64	0·62	481	H	M—	L+	M—	H+++
4. N.K. ,,	4	—P, Ca	3·07	0·57	0·86	0·40	333	M+	H—	L	M—	H+++
5. K. ,,	4	—P	4·12	0·40	0·73	0·42	367	H—	M+	L+	M—	H+++
6. N.P. ,,	2	—K, Ca; +Mn	2·10	0·43	0·61	0·70	300	M	M+	L	H—	H++++
7. P. ,,	4	—Ca; +Mn	3·25	0·52	0·56	1·20	394	M+	H—	M—	H+	H++++
8. Nil ,,	3	+Mn	3·06	0·62	0·79	0·48	335	M	H	M—	M—	H+++
9. Nil + 9 tons lime per acre	2	—P	3·12	0·20	4·59	0·28	108	M	L+	M+	L+	H—
10. N.P.K. ,, ,, ,, ,,	5	—Mg	4·08	0·25	4·35	0·67	119	H—	M—	M+	M+	H
11. P.K. ,, ,, ,, ,,	4	—N, Mg	3·71	0·18	5·59	0·38	136	M+	L	M+	L+	H
12. N.K. ,, ,, ,, ,,	3	—P	3·65	0·30	3·37	0·20	91	M+	M—	H—	L	H
13. K. ,, ,, ,, ,,	4	—P, Mg	4·71	0·13	4·11	0·21	75	H	L	M	M—	M
14. N.P. ,, ,, ,, ,,	3	—K	1·01	0·46	4·77	0·59	59	L+	M+	H—	M—	M
15. P. ,, ,, ,, ,,	3	—K	0·72	0·41	3·98	0·65	68	L	M	M+	M	M
16. Nil ,, ,, ,, ,,	2	—P	3·28	0·32	4·88	0·23	78	M	M—	H	L	M

* See ref (3).

in the Midlands, and the soil was strongly acid reclaimed in 1945 from heath. In general, the results of the 1946 experiment were corroborated.

2. Scorings for vigour showed that on the no lime plots Gladstone was least tolerant of the acidity complex; on the limed plots the best growth was made by Dunbar Rover and Kerr's Pink whilst Majestic failed to respond.

3. The best fertiliser treatment in the presence of lime was N P K, followed by P K, N K, K, N P, P and nil last. The most striking haulm responses to fertilisers were shown by Dunbar Rover, Kerr's Pink and Gladstone when K, P K, or N P K were given in the presence of lime.

4. All varieties showed deficiencies of N, P, K, Ca and Mg and excess of Mn according to treatment. Liming eliminated Ca deficiency and Mn excess. Appropriate fertiliser treatment eliminated deficiencies of N, P and K but not of Mg, which was not provided in the fertilisers.

5. A detailed account of the visual and tissue test data and full chemical analyses of Majestic is given and good agreement is shown between the three methods on major points.

6. It is suggested that Dunbar Rover is the most suitable variety to grow under these conditions after appropriate liming and fertilisers have been applied.

ACKNOWLEDGMENTS.

The assistance of Dr. T. W. Walker and Mr. Shaw of the N.A.A.S., West Midland Province, is gratefully acknowledged.

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MANURIAL EXPERIMENTS ON VEGETABLE CROPS.

XI. EFFECTS OF FARMYARD MANURE AND OF VARIOUS FERTILISER TREATMENTS ON CAULIFLOWER.

By D. J. D. NICHOLAS and E. CATLOW.

The cauliflower crop grown in 1946 was the eighth in the series of rotational vegetables grown on the plots since 1940 and followed potato grown in 1945. (4) The manurial treatments were as follows: N as nitrochalk at 8 cwt. per acre (4 cwt. in the base dressing followed by a top dressing at 4 cwt. per acre), P as superphosphate at 4 cwt. per acre, K as sulphate of potash at 2 cwt. per acre. The farmyard manure at 20 tons per acre was applied on 4/1/46 but severe frosts and heavy rain delayed ploughing under until 19/2/46. The inorganic fertilisers were broadcast on 15/5/46, and the top dressing of N applied on 4/7/46.

The cauliflower, var. Majestic, was sown on 14/3/46 and planted out on 30/5/46 with spacing intervals of 2 ft. by 2 ft. The dusting of plants with calomel dust was carried out immediately after planting. The season was particularly wet and the soil remained soft and wet for long periods during the growing period. Cutting of marketable heads commenced on 12/9/46 and continued for three weeks.

RESULTS.

Leaf Symptoms and Vigour.

The plants were scored for vigour and deficiency symptoms at intervals during the growing sesaon. In Table I are given vigour markings and leaf colour recorded early in the season. The maximum possible score for each plot is 4, making a total of 12 for three replicates.

TABLE I.

VIGOUR MARKINGS AND LEAF COLOUR, 7/8/46.

Manurial Treatment	Dung	N.P.K.	N.P.	N.K.	P.K.	N.	N.P.K. Cl	N.P.Na and Cl
Vigour marking	10	10	9	9	6	6	11	12
Leaf colour	medium green	dark green	dark green	dark green	pale green	dark green	very dark green	very dark green

The numerical marking shows that the omission of N or P and K are the main factors affecting crop vigour, whereas the leaf colour in the P K and dung plots indicates the presence of N deficiency. The plants treated with muriate of potash or salt are more vigorous at this early stage and had a darker leaf colour than those receiving sulphate of potash.

A more detailed record was made on 12/9/46 which included vigour marking and visual symptoms of the deficiencies for the various treatments. The numerical data for vigour are given in Table II ; the maximum possible per plot is 4, or 12 for the three replicate plots.

TABLE II.

VIGOUR MARKINGS, 12/9/46.

Treatments	Dung	N.P.K.	N.P.	N.K.	P.K.	N only	N.P.K. Cl	N.P.Na Cl
Block 1	3	4	3	2½	1½	2½	4	4
2	3	3½	3	3	2	2	3½	4
3	3	3½	2½	3½	1½	3	4	4
Total	9	11	8½	9	5	7½	11½	12
Order	4	3	4	5	6	7	2	1

The data show that the complete fertiliser is effective in producing a vigorous crop whether potash is included as the sulphate or the chloride and that N.P. NaCl is even better. The P K (omit N) plants are the least vigorous, thus emphasising the importance of nitrogen for this crop.

The main points with regard to the visual symptoms on 12/9/46, are as follows :—

F.Y.M. —Leaf colour generally pale with purple and yellow tints in the older leaves ; trace nitrogen deficiency, also trace magnesium deficiency.

N.P.K. —Leaf colour, fresh green ; slight to medium magnesium deficiency symptoms general.

N.P. (omit K) —Leaf colour, blue-green ; trace to slight potassium deficiency as a marginal scorch in the older leaves.

N.K. (omit P) —Leaf colour, dull green ; purple tints in older leaves ; probably trace phosphorus deficiency, and trace magnesium deficiency.

P.K. (omit N) —Leaf colour pale yellow with vivid purple red and yellow tints in the older leaves ; severe nitrogen deficiency ; mottling in older leaves due to medium magnesium deficiency.

N. (omit P & K) —Leaf colour, dull green, with trace purple and yellow tints in older leaves; probably P deficiency.

N.P.K.Cl —Leaf colour, slightly pale green, occasional purple and yellow tints and older leaves ; trace magnesium deficiency. Forward marginal curling in first upright leaves of a few plants with a marginal scorch; probably Cl excess.

N.P.Na.Cl —Leaf colour, slightly pale green dull purple and yellow tints in older leaves. Forward marginal curling of older leaves with occasional marginal scorch ; probably Cl excess.

It should be noted that the dull red and yellow tints in the older leaves of the cauliflower were general and occurred in most plots. These symptoms were those of nitrogen deficiency and were probably due to the leaching of the nitrate nitrogen from the top soil because of the persistent rainfall during the growing season. These symptoms were particularly marked in plants growing in waterlogged patches and soil analysis confirmed the absence of nitrate nitrogen in the surface soil of these wet areas.

The leaf symptoms in the F.Y.M. treatment were those of nitrogen deficiency together with trace magnesium deficiency. In the N.P.K. treatment in which K was given as sulphate, magnesium deficiency was more marked than in the dung plots. In the P.K. (omit N) treatments, nitrogen deficiency was severe and magnesium deficiency was even more pronounced than those of the N.P.K. plots. This demonstrates the importance of including magnesium in the fertiliser dressings when inorganic fertilisers are continually applied in the absence of organic manures.

When potash was not applied, as in the N.P. and N. treatments, the foliage was dull green and in the former treatment symptoms of potash deficiency were noted at this stage. These did not develop until late in the season in the N treatments. Symptoms of potash deficiency were not as severe as those of nitrogen deficiency.

The N.K. plants had dull tints of red and yellow in the older leaves. These were general and were probably those of phosphorus deficiency although a deficiency of nitrogen which produces similar effects might also be present. The trace Mg deficiency symptoms noted in a few plants growing in wet areas was associated with nitrogen deficiency.

The plants given chloride were paler green than those treated with N.P.K. as sulphate, although at the early stage the reverse was true. Magnesium deficiency was only present as a trace in the chloride plots as compared with slight to medium symptoms in the sulphate treatments. This suggests that chloride is not as antagonistic as the sulphate ion to the intake of magnesium. The marginal scorch effects in the chloride plots were probably associated with excess chloride. Toxic effects of chloride were noted in potato foliage grown during the previous season. (4)

Chemical Tissue Test Results.

The mineral status of the crop was determined using a chemical tissue test method (1, 2). The first upright leaf was taken as the test sample and a random selection was made of each plot and the following nutrients determined, K, Mg, Ca, PO_4, nitrate N, Cl and Mn. The data are given in Table III.

The main points are as follows :—

Potassium. When K is omitted as in the N and N.P. treatments the values are lower than when K is supplied. The levels however are on the threshold of deficiency viz. 25 to 60 p.p.m., thus confirming the trace K deficiency symptoms noted.

Magnesium. The values for the P.K. (omit N) treatment are at L^+, 2 p.p.m. thus confirming the medium to severe symptoms of the deficiency. The F.Y.M. plants also have low Mg values probably caused by N deficiency. The beneficial effect of nitrogen in increasing the magnesium values is shown in the N treatments when the levels are at M^+, 8 p.p.m. The application of potassium as the sulphate has depressed Mg values to L^+, 2 p.p.m., but when given as the chloride the level in the tissues is at M^+, 8 p.p.m.

Calcium. The values are adequate irrespective of treatment and this is in accord with the 2 to 5% free lime in the surface soil.

Phosphate. Although this nutrient has not been applied to the N and N.K. treatments since 1924 the tissue test values appear to be adequate except in plot 2 (N. only treatment) where symptoms of the deficiency were observed.

Nitrate nitrogen. It is noteworthy that the highest value recorded in any treatment is medium. This is probably due to the wet cold season inhibiting bacterial nitrification and to the leaching out of the soluble nitrate from the top soil. Despite lower values than for a normal season, differences between treatments are evident. When N is omitted, nitrate was not detected in the tissue extracts, and values for F.Y.M. plants are also low, thus confirming nitrogen deficiency. The M− values recorded in a few other treatments may be regarded as unsatisfactory levels associated with trace symptoms of the deficiency.

Chloride. The N.P.K.Cl and N.P.Na.Cl. treatments are reflected by very high values and the marginal scorch effects noted in the leaves may be due to chloride injury. The other treatments have normal chloride levels.

Manganese. Values for all treatments are adequate. When chloride is supplied there is a significant increase in the manganese content, the highest being 800 p.p.m. $\times 10^{-3}$. The effect of Cl in increasing the Mn content has been previously observed in flax (3).

TABLE III.

TISSUE TEST DATA FOR CAULIFLOWER UNDER VARIOUS MANURIAL TREATMENTS.
SAMPLING DATE, 12/9/46.

	TREATMENTS AND BLOCK NUMBERS																							
	N (omit P.K.)			N.P.K.			P.K. (omit N)			N.K. (omit P)			N.P. (omit K)			F.Y.M.			N.P.K. Cl			N.P.Na. Cl		
Block	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	3	5	2	4	6
K	*95 M	60 M—	95 M	165 H—	130 M+	165 H—	130 M+	165 H—	130 M+	130 M+	130 M+	130 M+	60 M—	25 L+	60 M—	130 M+	130 M+	165 H—	130 M+	165 H—	130 M+	200 H	165 H—	130 M+
Mg	8 M+	8 M+	8 M+	4 M—	2 L+	4 M—	2 L+	2 L+	2 L+	4 M—	6 M	4 M—	8 M+	10 H—	10 H—	4 M—	6 M	4 M—	8 M+	8 M+	8 M+	8 M+	8 M+	8 M+
Ca	200 M+	250 H—	250 H—	250 H—	250 H—	250 H—	250 H—	250 H—	250 H—	250 H—	200 M+	250 H—	250 H—	250 H—	250 H—	250 H—	200 M+	250 H—	250 H—	250 H—	250 H—	200 M+	200 M+	250 H—
PO4	30 M	10 L+	30 M	40 M+	40 M+	50 H—	50 H—	50 H—	40 M+	30 M	30 M	30 M	40 M+	40 M+	40 M+	50 H—	40 M+	40 M+	40 M+	60 H	40 M+	50 H—	50 H—	40 M+
NO3	150 M	100 M—	150 M	150 M	100 M—	150 M	0 Nil	0 Nil	0 Nil	100 M—	100 M—	100 M—	150 M	150 M	150 M	50 L+	50 L+	50 L+	150 M	100 M—	150 M	100 M—	150 M	150 M
Cl	20	20	20	10	20	10	20	20	20	10	20	20	10	10	20	20	10	10	75 H+	75 H+	50 H	100 H++	100 H++	75 H+
Mn as p.p.m. $\times 10^{-3}$	60	60	60	40	75	50	40	40	75	60	40	50	75	80	80	50	60	50	200	500	200	800	800	800

Key : H = high. M = medium. L = low.
* Figures denote p.p.m. of nutrient in the Morgan's extract ; Mn as p.p.m. $\times 10^{-3}$

Yield Results.

Yields were taken of marketable and total heads cut and the results analysed statistically, excepting the chloride treatments which are not strictly comparable. The statistical analyses are given in Tables IV and V and the crop weights for the chloride treatments are included for comparison.

TABLE IV.

MARKETABLE HEADS CUT SHOWING MEAN YIELDS (TONS PER ACRE) AND ORDER OF YIELDS

Manurial Treatment	F.Y.M.	N.P.K.	N.P.	N.K.	P.K.	N.	N.P.K. Cl	N.P.Na Cl
Yields—Tons	1·31	2·88	1·44	1·77	0·24	1·63	3·11	2·99
Order of Yields	5	1	4	2	6	3		

S.E. = 0·31 ; S.D. 5% = 0·96 ; 1% = 1·37.

At 5% point : 1, 2, 3, 4, 5, > 6
1 > 2, 3, 4, and 5

At 1% point : 1, 2, 3 > 6
1 > 4 and 5

TABLE V.

TOTAL NUMBER OF HEADS CUT, SHOWING MEAN YIELDS (TONS PER ACRE) AND ORDER OF YIELDS

Manurial Treatment	F.Y.M.	N.P.K.	N.P.	N.K.	P.K.	N.	N.P.K. Cl	N.P.Na Cl
Yields—Tons	2·67	4·25	3·19	2·91	0·75	2·57	4·81	5·82
Order of Yields	4	1	2	3	6	5		

S.E. = 0·43 ; S.D. 5% = 1·36 ; S.D. 1% = 1·93.

At 5% point : 1, 2, 3, 4, 5, > 6
1 > 4 and 5

At 1% point : 1, 2, 3 > 6

The results for marketable and total yields show that the omission of nitrogen (P.K.) is the main factor in depressing yields. The F.Y.M. treatment also gave a relatively low yield due to the low N status, which was observed in the foliage and confirmed by chemical tissue tests. It is therefore necessary to supplement an organic manure of this type with an inorganic supply of nitrogen.

The N.P.K. treatments had the highest yield despite the presence of visual signs of magnesium deficiency. This deficiency was well developed

in the P.K. treatments but the depression in yield was mainly due to nitrogen deficiency.

The omission of potash or phosphate does not affect the yields of total heads but the omission of both reduces the total yields. The omission of K reduces the weight of marketable heads but its effect is not as serious as that of nitrogen deficiency. This is in accord with the chemical tissue tests which show a greater differentiation of the N than of the K levels in the plants. The brassica crops, as in previous years, were adversely affected by the lack of nitrogen whereas potash deficiency did not reduce yields as in potato (4).

The N.P.K.Cl and N.P.Na.Cl treatments have high yield values despite the appearance of marginal scorch effects which were attributed to chloride injury and confirmed by tissue analysis. Chloride increased the manganese level in the tissues and may prove of value in alleviating Mn deficiency.

Summary and Conclusions.

1. Cauliflower, var. Majestic, was grown on a long term manurial trial in which various N.P.K. and F.Y.M. treatments are represented. The crop was the eighth of the rotational series, the previous crop being potato.

2. Data were obtained for vigour of haulm, foliage characters, including visual symptoms of deficiencies and excesses, mineral status of foliage and yields of marketable and total heads.

3. The manurial treatments were reflected in the vigour markings, and visual symptoms and rapid chemical tests showed differences in the N.P.K. Mg and Cl levels of the plants. Magnesium deficiency was associated with the P.K., N.P.K. (as K_2SO_4) and dung plots, in that order of severity, whereas chloride treatment alleviated the deficiency.

4. Nitrogen deficiency proved to be the main limiting factor with regard to yield whilst the mild effects of K deficiency did not markedly affect the growth and development of the "heads." The yields of the F.Y.M. plots were lower than those of N.P.K., probably due to insufficient nitrogen. The chloride treatments although causing injury to the foliage, gave very high yield figures.

5. The chemical tissue test data confirm the visual effects in showing that when N deficiency was marked the Mg values were low, K levels were lower when K was omitted, P deficiency was present in one of the N.K. plots, Cl excess was present in the N.P.KCl and N.P. NaCl plots and these plants had a higher Cl and Mn status than other treatments.

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MANURIAL EXPERIMENTS ON VEGETABLE CROPS.

XII. EFFECTS OF FARMYARD MANURE AND OF VARIOUS FERTILISER TREATMENTS ON THREE VARIETIES OF POTATO.

By D. J. D. NICHOLAS and E. CATLOW

Three varieties of potato, viz. Majestic, Red King and Kerr's Pink, were grown during the 1947 season. These followed cauliflower (1) and were the ninth crop of the vegetable rotation which was started on these plots in 1940. The fertiliser treatments included N as sulphate of ammonia at 3 cwt. per acre, P as superphosphate (16·5%) at 4½ cwt. per acre, K as sulphate of potash at 2 cwt. per acre, or as chloride at 2 cwt. per acre, Na as sodium chloride at 2 cwt. per acre. The farmyard manure was applied at the rate of 20 tons per acre on 24/1/47 and the other fertilisers broadcast on 25/4/47.

The three varieties were planted on 12/5/47 with spacing intervals of 2′ 6″ by 1′ 6″. A copper spray was applied on 6/8/47 and this prevented blight infection. Harvesting was carried out on 20/10/47 when the haulms had died back.

RESULTS.

Leaf Symptoms and Vigour.

During the season the crops were scored for vigour and deficiency and toxicity symptoms in the haulms. The results are summarised in Tables I, II and III, and where numerical values are given, these are the sum of three replicates and the maximum total is 12.

June 16th. These records were taken prior to the earthing up stage. At this period the Kerr's Pink variety was the most forward whereas Red King was the least vigorous.

TABLE I.

Vigour Markings and Visual Symptoms of Mineral Deficiencies, 16/6/47.

Manurial Treatment	F.Y.M.	N.P.K.	N.P.	N.K.	P.K.	N.	N.P.K. Cl	N.P.Na Cl
Vigour Marking	8½	10	7½	7½	6	6	10	10
Leaf Colour	Pale green	Dark green	Very dark green	Dark green	Very pale green	Very dark green	Dark green	Dark green
Visual symptoms	Trace N deficiency	Trace Mg deficiency	Nil	Nil	Slight N, and trace Mg deficiency	P deficiency habit	Nil	Nil

The N.P.K. sulphate and chloride treatments are equally vigorous although trace Mg deficiency was observed in the first named treatment. Symptoms of magnesium deficiency were observed at this stage in Kerr's Pink and Red King but not in Majestic. The P.K. plants were the least vigorous, having very pale green foliage, i.e. nitrogen deficiency, and in addition trace Mg deficiency. The F.Y.M. although more vigorous than P.K. plants, had pale green foliage indicating a shortage of nitrogen. The N treatment had a low vigour marking and trace P deficiency was observed. Further, the dark green leaf colour might be associated with a low K content.

August 1st. Further records were made at this date and in addition chemical tissue tests were carried out on samples taken from each plot. The visual data are given in Table II.

TABLE II.

VIGOUR MARKINGS AND VISUAL SYMPTOMS OF MINERAL DEFICIENCIES, 1/8/47.

Manurial Treatment	F.Y.M.	N.P.K.	N.P.	N.K.	P.K.	N.	N.P.K. Cl	N.P.Na Cl
Vigour marking	9	11	7	9	4	6½	12	12
Leaf Colour	Pale green	Medium green	Very dark green	Dark green	Very pale green	Dark green	Pale green	Pale green
Visual Symptoms	Slight N and trace Mg deficiency	Slight to medium Mg deficiency	Medium K deficiency	Trace P deficiency habit	Severe N and medium to severe Mg deficiencies	Trace P deficiency habit	Nil	Nil

TABLE III.

VIGOUR MARKINGS AND VISUAL SYMPTOMS OF MINERAL DEFICIENCIES AND TOXICITIES, 27/8/47.

Manurial Treatment	F.Y.M.	N.P.K.	N.P.	N.K.	P.K.	N.	N.P.K. Cl	N.P.Na Cl
Vigour marking	9	10½	6	9	3	7	11	12
Leaf Colour	pale green	medium green	very dark green	medium green	very pale green	dark blue green	pale green	pale green
Visual Symptoms	Slight N and trace Mg deficiencies	Medium Mg deficiency	Medium to severe K deficiency	Trace P deficiency habit and trace Mg deficiency	Severe N and medium to severe Mg deficiencies	Slight to medium K deficiency	Trace chloride injury	Trace chloride injury

The vigour data show that N is important for crop performance, as the P.K. plants have fallen from 6 to 4 as compared with the previous record and the deficiency was severe at this stage. Magnesium deficiency occurred in the P.K., N.P.K. and F.Y.M. plots whereas none was noted in the chloride treatments. In the last-named plots the foliage was pale green at this date as compared with dark green on the 16th June. This change was probably the result of the intake of chloride by the plants. Potash deficiency appeared in the N.P. plots whereas the P deficiency habit was noted in the N treatments.

August 27th. A further record was made late in the season when effects due to chloride injury were first observed. The visual data are presented in Table III.

Nitrogen deficiency appears to be the main factor in reducing vigour. Magnesium deficiency is particularly marked when nitrogen is omitted as in the P.K. treatments. The P.K., N.P.K., F.Y.M. and N.K. treatments had symptoms of magnesium deficiency in that order of severity whereas the N.P., N and chloride plots continued to be free from the symptoms. Potash deficiency reduced the vigour marking of the N.P. plot and symptoms were also observed in the N plants which had hitherto only shown the P deficiency habit. Chloride injury was manifest in the N.P.KCl and N.P.NaCl treatments at this stage but the effects were not severe. The pale green foliage was probably associated with the high Cl level in the tissues.

Varietal differences in susceptibility to mineral deficiencies were observed. The chief point of difference was in the greater susceptibility of Kerr's Pink and Red King to magnesium deficiency than Majestic. This deficiency also provided variations in leaf effects. Kerr's Pink had striking intervenal chlorosis in the older leaves with necrotic patches and a marginal green band, whereas at a later stage, the leaves had a marginal yellow band with a partial greening of the intervenal chlorotic tissue. Red King and Majestic had a more general intervenal chlorosis extending to the periphery of the leaf with irregular necrotic areas.

Chemical Tissue Test Results.

Tissue test data for K, Mg, Ca, PO_4, nitrate N and Mn were obtained for Kerr's Pink and Majestic. The results are presented in Tables IV and V.

The main points of interest are as follows :—

Potassium. When K is omitted as in the N.P. and N treatments the K values are lower than when it is supplied. The N.P. treatments have the lowest levels and this is in accord with the presence of symptoms of the deficiency. Although visual signs were not observed in the N treatments at this date, the chemical result is on the threshold of deficiency. The N.P. NaCl plants have a high level, thus under these conditions salt facilitates the availability of potash to the plants.

Magnesium. The P.K. (omit N), N.P.K. and F.Y.M., have the lowest values in that order in both varieties. Kerr's Pink has lower levels than Majestic and this is in accord with the greater susceptibility of the former to the deficiency. When K is omitted or chloride applied the Mg values are high and symptoms of the deficiency were absent.

Calcium. The values are adequate and this is in accord with the presence of approximately 5% free lime in the surface soil, irrespective of treatment.

Phosphate. Threshold values for the deficiency were recorded in the N and N.K. treatments and this is in agreement with the trace of visual signs of the deficiency.

TABLE IV.

TISSUE TEST DATA FOR KERR'S PINK UNDER VARIOUS MANURIAL TREATMENTS. SAMPLING DATE, 5/8/47.

Figures denote p.p.m. of nutrient in the Morgan's Extract.

	TREATMENTS AND BLOCK NUMBERS																							
	N (omit P.K.)			N.P.K.			P.K. (omit N)			N.K. (omit P)			N.P. (omit K)			F.Y.M.			N.P.K. Cl			N.P. Na Cl		
Block	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
K	50 M—	25 L+	50 M—	150 H	150 H	150 H	100 M+	125 H—	150 H	150 H	100 M+	150 H	25 L+	25 L+	25 L+	100 M+	75 M	100 M+	100 M+	150 H	150 H	150 H	125 H—	125 H—
Mg	6 M	8 M+	8 M+	4 M—	4 M—	4 M—	2 L+	2 L+	2 L+	6 M	8 M+	8 M+	12 H	12 H	14 H+	4 M—	6 M	4 M—	12 H	12 H	8 M+	10 H—	12 H	10 H—
Ca	125 H—	150 H	150 H	125 H—	125 H—	150 H	100 M+	150 H	125 H—	125 H—	150 H	150 H	200 H++	175 H+	200 H++	125 H—	150 H	150 H	150 H	125 H—	125 H	100 M+	150 H	150 H
PO_4	5 L+	10 M—	5 L+	20 M+	20 M+	20 M+	20 M+	25 H—	25 H—	5 L+	5 L+	5 L+	20 M+	25 H—	25 H—	20 M+	25 H—	20 M+	20 M+	20 M+	20 M+	25 H—	20 M+	25 H—
NO_3	150 H	100 M+	150 H	150 H	125 H—	150 H	0 Nil	0 Nil	0 Nil	100 M+	125 H—	125 H—	200 H+	150 H	200 H+	25 L+	5 L	25 L+	100 H	125 H—	200 H+	150 H	200 H+	150 H
Cl	25 M+	25 M+	25 M+	25 M+	25 M+	25 M+	25 M+	25 M+	10 M	10 M	10 M	10 M	25 M+	10 M	25 M+	25 M+	25 M+	10 M	100 H+	100 H+	150 H+++	100 H+	125 H++	150 H+++
Mn in p.p.m. $\times 10^{-3}$	60	50	50	50	40	40	30	30	30	30	30	30	70	70	70	20	30	30	80	100	80	100	100	100

TABLE V.

TISSUE TEST DATA FOR MAJESTIC UNDER VARIOUS MANURIAL TREATMENTS. SAMPLING DATE, 5/8/46.
Figures denote p.p.m. of nutrient in the Morgan's extract.

	TREATMENTS AND BLOCK NUMBERS																							
	N (omit P.K.)			N.P.K.			P.K. (omit N)			N.K. (omit P)			N.P. (omit K)			F.Y.M.			N.P.K. Cl			N.P.Na Cl		
Block	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
K	50 M—	25 L+	50 M—	100 M+	150 H	100 M+	125 H—	150 H	150 H	125 H—	150 H	125 H—	25 L+	10 L	25 L+	100 M+	100 M+	125 H—	150 H	150 H	150 H	150 H	150 H	150 H
Mg	14 H+	14 H+	14 H+	6 M	4 M—	4 M—	4 M—	2 L+	4 M—	8 M+	8 M+	8 M+	14 H+	20 H+	14 H+	6 M	4 M	6 M	14 H+	14 H+	12 H	14 H+	12 H	14 H+
Ca	100 M+	150 H	100 M+	150 H	125 H—	125 H—	125 H—	150 H	100 M+	100 M+	125 H—	100 M+	200 H+	150 H	150 H	100 M+	150 H	150 H	150 H	150 H	150 H	150 H	150 H	100 M+
PO_4	10 M—	10 M—	5 L+	25 H—	25 H—	25 H—	30 H	25 H—	20 M+	5 L+	5 L+	5 L+	20 M+	20 M+	25 H—	20 M+	20 M+	20 M+	20 M+	30 H	20 M+	30 H—	25 H	25 H—
NO_3	200 H+	150 H	200 H+	150 H	200 H+	150 H	0 Nil	0 Nil	0 Nil	200 H+	150 H	200 H+	200 H+	125 H—	200 H+	10 L	10 L	10 L	150 H	150 H	200 H+	150 H	150 H	200 H+
Cl	25 M+	25 M+	25 M+	25 M+	25 M+	25 M+	25 M+	25 M+	25 M+	25 M+	10 M	10 M	10 M	25 M+	25 M+	10 M	25 M+	25 M+	100 H+	75 H	75 H	125 H++	125 H++	100 H+
Mn p.p.m. $\times 10^{-3}$	60	40	40	60	80	80	60	40	50	80	40	60	80	80	80	20	20	30	100	150	100	150	100	150

Nitrate Nitrogen. The severe deficiency in the P.K. plants is confirmed by the absence of nitrate nitrogen in the tissue extract. The values for the F.Y.M. treatment are also at the deficiency level. There is a correlation between the low N and low Mg values.

Chloride. The chloride treatments are reflected and visual signs of injury were apparent late in the season.

Manganese. The values are adequate throughout. The F.Y.M. plants have the lowest values probably due to the biological fixation of Mn in the presence of added organic matter in a calcareous soil. When K is omitted, and in particular when chloride is applied, the Mn values are much higher. It appears that Cl has a marked effect on the availability of Mn to the plants in this soil.

Yield Results.

Yields were taken of total crops and ware and the results analysed statistically, excepting the chloride treatments, which are not strictly comparable. The yields for the last-named treatments are included to provide rough comparisons. The varietal effects were also analysed and are given in Tables VI and VII.

TABLE VI.

TOTAL YIELDS SHOWING MEAN YIELDS (TONS PER ACRE) AND ORDER OF YIELDS.

(A) MANURIAL EFFECTS.

Manurial Treatments	F.Y.M.	N.P.K.	N.P.	N.K.	P.K.	N.	N.P.K. Cl	N.P.Na Cl
Yields—Tons	9·44	11·0	9·29	10·67	6·69	8·37	12·38	13·02
Order of Yields	3	1	4	2	6	5		

S.E. = 0·46. S.D. 1% = 1·96.

At 1% point 1 and 2 > 5 and 6 ;
1, 2, 3, 4 > 6

(B) VARIETAL EFFECTS.

Varieties	Red King	Kerr's Pink	Majestic
Yields—Tons	7·43	11·37	8·90
Order Yields	3	1	2

S.E. 0·2 ; S.D. 1% = 0·72

At 1% point 1 > 2 > 3

TABLE VII.

YIELDS OF WARE. SHOWING MEAN YIELDS (TONS PER ACRE) AND ORDER OF YIELDS.

(A) MANURIAL EFFECTS.

Manurial Treatment	F.Y.M.	N.P.K.	N.P.	N.K.	P.K.	N.	N.P.K. Cl	N.P Na Cl
Yields—Tons	8·77	10·39	9·01	10·07	6·18	7·95	11·25	12·05
Order of Yields	4	1	3	2	6	5		
% Total Yields	92·9	94·45	96·98	94·37	92·37	94·98	91·61	92·54

Yields S.E. = 0·46; S.D. 1% = 2·07

At 1% point 1, 2 > 5 and 6
1, 2, 3, 4, > 6

(B) VARIETAL EFFECTS.

Varieties	Red King	Kerr's Pink	Majestic
Yields—Tons	7·07	8·60	10·51
Order of Yields	3	2	1
% Total Yields	95·15	75·63	84·68

Yields S.E. = 0·19; S.D. 1% = 0·77

At 1% point 1 > 2 > 3

Total and ware yields show that the N.P.K. and N.K. treatments give high values. It seems that medium Mg deficiency and trace P deficiency noted in the two treatments respectively, did not appreciably affect the yields.

Total yields for N.P.K. and N.K. were significantly greater than for F.Y.M. and P.K. treatments and this shows the importance of nitrogen and that it is necessary to add a nitrogenous fertiliser to F.Y.M. to produce high yields. Symptoms of nitrogen deficiency were observed in the F.Y.M. plots early in the season and confirmed by chemical tissue tests. The ware values also confirm the depressing effect of nitrogen deficiency on yields. It was also shown that the omission of P and K together resulted in a marked depression as compared with the N.P.K. treatments.

Potash deficiency reduced the yield figures but not to the same extent as nitrogen deficiency. This is in accord with the severe symptoms of N deficiency in the low N plots and milder effects caused by K deficiency in the N.P. and N treatments.

The yields of the two chloride plots are high and this shows that the trace of chloride injury observed late in the season did not appreciably affect crop weights.

As in previous years, the three varieties were in the following ascending order with regard to total yields, Red King < Majestic < Kerr's Pink whereas that of the ware values was Red King < Kerr's Pink < Majestic. The latter grouping may be regarded as an approximate guide to the susceptibility of the varieties to the deficiencies observed, especially those of nitrogen and magnesium.

SUMMARY AND CONCLUSIONS.

1. Potato varieties Majestic, Kerr's Pink and Red King were grown in a well-established manurial trial on which the effects of farmyard manure and various fertiliser treatments were studied. The crops were the ninth in the vegetable rotation and followed cauliflower.

2. Results are given for the vigour of the haulm, foliage characters, including visual symptoms of deficiencies and toxicities, chemical tissue tests, total crop weights and yields of ware.

3. The manurial treatments were reflected by the vigour markings of the haulms and visual symptoms recorded at intervals during the season. Deficiencies of N (severe), P (trace), K (medium) Mg (trace to medium) and Cl toxicity (trace) were observed. Magnesium deficiency was marked when N was omitted and also in the N.P.K_2SO_4 treatment but was absent from N.P.KCl plots. The F.Y.M. plants had a low N status and Mg deficiency (trace) was also noted.

4. Chemical tissue tests for K, Mg, Ca, PO_4, nitrate N, Cl and Mn in Majestic and Kerr's Pink confirmed the visual symptoms. The following effects were observed (a) N status was low in P.K. and F.Y.M. plants, (b) Mg values were low in the P.K. (omit N), N.P.K., F.Y.M. plants but were high when K was omitted or Cl applied, (c) P values in the N and N.K treatments were at the threshold of deficiency level, (d) very high Cl values were recorded in the chloride treatments and the Mn values were higher than for any other treatment.

Kerr's Pink had lower Mg values than Majestic.

5. Nitrogen and potassium deficiencies were, in that order, the most serious limiting factors with regard to ware and total yields. The F.Y.M. treatment gave low values probably due to insufficient nitrogen. Although P deficiency habit was noted early in the season in the N.K. plots, the yields were not affected.

The chloride treatments had high yields comparable to those of N.P.K. sulphate plots, although symptoms of chloride injury were noted late in the season.

6. Varietal effects for total yields were in the following order Kerr's Pink > Majestic > Red King and ware yields Majestic > Kerr's Pink > Red King. The latter variety was most affected by mineral disorders.

REFERENCES.

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(2) Wallace, T. and Catlow, E. (1945). Manurial experiments on vegetable crops. IX. Effects of farmyard manure and of various fertiliser treatments on three varieties of potato. *Long Ashton* 1945 *Ann. Rept.*, p. 95.

MANURIAL EXPERIMENTS ON VEGETABLE CROPS.

XIII. EFFECTS OF FARMYARD MANURE AND OTHER MANURIAL TREATMENTS ON POTATO AND CAULIFLOWER. SEASONS 1946 AND 1947.

By D. J. D. NICHOLAS and E. CATLOW.

Three varieties of potato viz. Majestic, Kerr's Pink and King Edward were grown on a manurial trial, which had been used for continuous vegetable cropping (1). The potato crop followed garden beet (2) and was the eighth in the rotational series (1946). Cauliflower var. Majestic was grown the following year (1947).

Manurial Treatments.

Details of the manurial treatments are given in Table I.

TABLE I.

MANURIAL TREATMENTS.

Notation	Potato (1946)	Rate per acre	Cauliflower (1947)	Rate per acre
A	F.Y.M. (organic matter 19%)	20 tons	F.Y.M. (organic matter 14%)	20 tons
B	F.Y.M. Sulphate of ammonia (20% N)	10 tons. 1½ cwt.	F.Y.M. Nitrochalk (15½% N)	10 tons 2 cwt.
C	Vegetable compost (organic matter 12%) Sulphate of ammonia	15½ tons 1½ cwt.	Vegetable compost (organic matter 10%) Nitrochalk	11½ tons 2 cwt.
D	Hoof and horn (12% N) Superphosphate (18% P_2O_5) Sulphate of potash (48% K_2O)	10 cwt. 4 ,, 2 ,,	Hoof and horn (13% N) Superphosphate (16½% P_2O_5) Sulphate of potash (48% K_2O)	9½ cwt. 4½ ,, 2 ,,
E	Sulphate of ammonia Superphosphate Sulphate of potash	3 cwt. 4 ,, 2 ,,	Nitrochalk Superphosphate Sulphate of potash	4 cwt. 4½ ,, 2 ,,
F	Sulphate of ammonia Superphosphate Potash salts (30% K_2O)	3 cwt. 4 ,, 3⅕ ,,	Nitrochalk Superphosphate Potash salts (30% K_2O)	4 cwt. 4½ ,, 3⅕ ,,
G	Sewage sludge, straw compost (organic matter 15·5%)	24½ tons	Sewage sludge, straw compost (organic matter 13·1%)	21½ tons
H	Sulphate of ammonia Superphosphate Sulphate of potash Calcined kieserite (Magnesium sulphate)	3 cwt. 4 ,, 2 ,, 1 ,,	Nitrochalk Superphosphate Sulphate of potash Calcined kieserite (Magnesium sulphate)	4 cwt. 4½ ,, 2 ,, 1 ,,

The bulky organic manures were applied on 5/1/46 and 24/1/47 prior to ploughing and the remainder, on 3/4/46 and 28/5/47. In addition a top dressing of nitrochalk was applied on 15/7/47 to the cauliflower, at 4 cwt. per acre to treatments D, E, F and H and at 2 cwt. per acre to B and C.

The potato sets were planted out on 16/4/46 and each plot had 3 rows of Majestic, Kerr's Pink and King Edward respectively. The potatoes were

sprayed with Bordeaux mixture on 4/7/46 and 8/8/46 and this prevented blight infection. The cauliflower were planted on the 16/6/47 and calomel dust was applied two days later to prevent root fly attack. In addition D.D.T. dust was applied on 12/8/47 to prevent cabbage white caterpillar infection.

The 1946 season was notable for its persistent rainfall and the soil in most of the plots was wet and waterlogged for long periods during the growing season. Harvesting was carried out on 29/10/46 during a dry period.

During 1947 conditions were more favourable for growth. Cutting of heads of cauliflower commenced on 20/9/47 and continued until 30/10/47 making a total of six cuttings.

RESULTS.

Potato : 1946.

Vigour markings and records of deficiency symptoms were made in all plots at intervals during the season. The maximum marking per plot was 5 making a total of 15 for the three replicates. The results are given in Table II.

TABLE II.

VIGOUR MARKING AND LEAF COLOUR ON 7/8/46.

Manurial Treatment	F.Y.M. 20 ton	F.Y.M. 10 tons 1½ cwt. sulphate of ammonia	Vegetable compost equivalent 10 ton F.Y.M. + 1½ cwt. sulphate of ammonia	Complete N.P.K. with Hoof	Complete Inorganic N.P.K. with K_2SO_4	Complete N.P.K. with Potash Salts	Straw Sludge compost	Complete Inorganic N.P.K. + Mg SO_4
Notation	A	B	C	D	E	F	G	H
Vigour marking	13	12	12	15	12	12	12	11
Leaf colour	Pale green	Pale green	Pale green	Medium green	Medium green	Medium green	Medium green	Medium green

At this stage there were no striking differences in vigour. The pale green leaf colour in plots A, B and C was associated with nitrogen deficiency.

A further record was made on the 13/9/46 which included vigour marking and visual symptoms and the data are given in Table III.

The outstanding plot with regard to vigour was D, (N.P.K. with hoof) although trace Mg deficiency was observed at this stage. The N.P.K. as chloride and N.P.K. as sulphate have similar vigour markings. Chloride injury was observed in the first named and Mg deficiency in the sulphate treatment. The compost treatments either supplied alone, as in G, or supplemented with nitrogen, as in B and C, had reduced vigour markings probably due to nitrogen deficiency. The N.P.K. Mg treatment (H) although free from symptoms was not as vigorous as plot D. The reason for this is not clear but it may be due to the fact that prior to 1940 plot (H) was not given any manure.

TABLE III.

VIGOUR MARKING AND VISUAL SYMPTOMS ON 13/9/46.

Notation	A	B	C	D	E	F	G	H
Vigour marking	10	11	11	14	12	12	10	11
Leaf colour	Very pale green	Pale green	Pale green	Medium green	Medium green	Pale foliage	Pale green	Medium green
Visual symptoms	Slight N deficiency Trace Mg deficiency	Trace N and Mg deficiencies	Trace N deficiency	Trace Mg deficiency	Medium Mg deficiency	Cl toxicity	Trace Mg and N deficiency	Nil

Chemical Tissue Tests.

Chemical tissue tests were carried out on the three varieties on 15/9/46. The mean results for the three replicates for K, Mg, Ca, PO_4, N and Cl are given in Table IV.

The main points are as follows :—

Potassium. The values are adequate throughout and are usually higher in plots treated with potash as the sulphate or chloride.

Magnesium. The lowest values are recorded in the N.P.K. sulphate treatment, and deficiency levels occur when bulky organics are applied (plots A and G) but the addition of nitrogen to these increased the Mg level in the tissues and alleviated the deficiency (B). The values are higher when potash was used as the chloride (F) or when magnesium sulphate had been applied (H). Edward and Kerr's Pink tend to have lower values than Majestic for the same treatment, and the former two varieties were more susceptible to the deficiency.

Calcium. The levels are adequate irrespective of treatment. This is in accord with 5% free lime in the top soil.

Phosphate. The values are normal and tend to be higher in the presence of an inorganic supply of P.

Nitrate nitrogen. The results show that bulky organic manures do not supply sufficient nitrogen for the growth of potato. The addition of half the normal dosage of inorganic N as a supplement has increased the N status of the tissues but the values are at the threshold of deficiency level. This may be due to heavy rain during early season which leached out the soluble nitrogen from the rooting zone.

Chloride. High values are recorded in the potash salts treatment (F) and this is in accord with symptoms of chloride injury observed viz., pale foliage with a greyish brown marginal scorch in the younger leaves.

Yield Results.

Yields were taken for total crop and ware and the results analysed statistically. Varietal yields were also included in the analysis. The data are given in Table V.

TABLE IV.

TISSUE TEST RESULTS FOR K, MG, CA, PO_4, NO_3 AND Cl IN MAJESTIC, KERR'S PINK AND EDWARD. SAMPLED 15/9/46

Notation	A			B			C			D			E			F			G			H		
Variety*	M	K.P.	K.E.	M	K.P.	K.E.	M	K.P.	K.E.	M	K.P.	K.E.	M	K.P.	K.E.	M	K.P.	K.E.	M	K.P.	K.E.	M	K.P.	K.E.
K	H—	M+	H—	M+	H—	H—	M+	M+	H—	H	H	H	H	H+	H	H+	H	H+	M+	H—	H—	M+	M+	M+
Mg	M	L+	L+	M+	M—	M—	M+	M	M	M—	L+	L+	L+	L	L	M+	M+	M+	M	M—	L+	M+	M+	M+
Ca	H—	M+	H—	H—	H—	H	H—	H	H	H	H—	H—	H	H	H	H	H	H	H	H	H—	H—	H—	H
PO_4	H—	M+	H—	M+	M+	M+	H—	M+	M+	H	H	H	H	H	H	M+	H—	M+	M+	M+	H—	M+	H—	H—
NO_3	L	L	L+	M	M—	M—	M	M—	M—	H—	H—	H—	H—	H—	H	H—	H—	H	M—	L+	L+	M+	H—	M+
Cl	M+	M	M+	M	M+	M	M	M	M	M	M+	M+	M+	M+	M+	H++	H++	H+	M+	M+	M+	M+	M+	M+

Key: H = High, M = Medium, L = Low (See p. 113 for quantitative values).

* M = Majestic, K.P. = Kerr's Pink, K.E. = Edward.

TABLE V.

TOTAL YIELDS. SHOWING MEAN YIELDS (TONS PER ACRE) AND ORDER OF YIELDS AND VARIETAL DIFFERENCES.

Manurial-Treatment / Variety	A	B	C	D	E	F	G	H	Mean
Majestic	17·49	17·97	16·01	18·86	16·31	15·93	13·56	15·32	16·43
Kerr's Pink	16·39	17·06	16·55	20·03	16·96	16·01	14·79	13·76	16·45
King Edward	12·53	13·02	12·27	15·43	11·90	12·67	8·69	9·91	12·06
Mean	15·48	16·01	14·94	18·10	15·07	14·87	12·37	13·01	14·98
Order of Yields	3	2	5	1	4	6	8	7	

S.E. Variety = 0·27 S.D. Variety at 1% = 1·04

S.E. Manure = 0·78 S.D. Manure at 1% = 3·29

at 5% = 2·37

At the 5% point D > A, C, E, F, G, H; B > G, H.
A, B, C, D, E, F > G; A, B, D > H.

At the 1% point (1) B, D > G; D > H, G.
(2) Majestic and Kerr's Pink > King Edward.

TABLE VI.

WARE YIELDS. SHOWING MEAN YIELDS (TONS PER ACRE) AND ORDER OF YIELDS AND VARIETAL DIFFERENCES

Treatment / Variety	A	B	C	D	E	F	G	H	Mean
Majestic	16·42	17·25	15·48	18·08	15·24	15·37	12·45	14·57	15·61
Kerr's Pink	13·76	14·06	14·46	17·97	15·0	14·44	10·77	11·01	13·93
King Edward	10·95	11·55	10·74	13·98	10·55	10·95	7·42	8·57	10·59
Mean	13·72	14·28	13·56	16·67	13·60	13·59	10·21	11·39	13·39
Order of Yields	3	2	6	1	4	5	8	7	
Ware as % Total Yields	88·63	89·20	90·74	92·11	90·22	91·35	82·66	87·64	90·51
Order of Ware % Total Yields	6	5	3	1	4	2	8	7	

S.E. Manures = 0·28
S.E. Variety = 0·91

S.D. Manures 1% = 3·83
5% = 2·76
S.D. Variety at 1% = 1·10

At 5% point D > A, C, E, F, G, H; A, B, C, D, E, F, > G.

At 1% point (1) B, D > G; D > H.
(2) Majestic > Kerr's Pink > Edward.

Both total and ware yields show that one of the best treatments was N.P.K. as sulphate with hoof (D), and in addition it had the highest percentage ware to total yields. The straw sludge compost (G) had the lowest total, ware, and percentage ware to total yields. The visual and chemical data show that nitrogen and magnesium deficiencies were present in this plot and that the first-named was probably the main limiting factor. The F.Y.M. + sulphate of ammonia treatment (B) is comparable with D being significantly greater thin G. This demonstrates the importance of incorporating an inorganic source of nitrogen in organic manures for high yield values. The anomalous result, that the total and ware yields of N.P.K. as sulphate + hoof (D) is significantly greater than N.P.K. + magnesium sulphate (H) may be explained in terms of extra nitrogen in the former treatment and that treatment (H) prior to vegetable cropping was a no manure plot (I).

The total yields for the varieties were in the following ascending order, King Edward < Kerr's Pink and Majestic and for ware yields King Edward < Kerr's Pink < Majestic. The tissue test and visual data confirm that Edward was adversely affected by manurial disorders. The order given for the ware yields may be regarded as a rough guide to the susceptibility of the varieties to unfavourable manurial treatments.

Cauliflower: 1947.

Vigour markings and records of visual symptoms of mineral deficiencies were taken for all plots. The maximum vigour marking per plot was 5 making a total of 15 for the three replicates. The results for 11/8/47 are given in Table VII.

TABLE VII.

Vigour Marking, Leaf Colour and Visual Symptoms of Deficiencies, 11/8/47.

Notation	A	B	C	D	E	F	G	H
Vigour Marking	10	9	9	11	11½	11	8½	11
Leaf Colour	Pale green	Medium green	Medium green	Dark green	Medium green	Medium green	Very pale green	Medium green
Visual Symptoms	Trace N deficiency	Nil	Nil	Nil	Nil	Nil	Slight N deficiency	Nil

The main point of interest at this stage is the presence of nitrogen deficiency in the straw sludge compost (G) and F.Y.M. (A) treatments. In addition the

former had the lowest vigour marking thus showing the inadequacy of bulky organic manures alone as a source of nitrogen for cauliflower.

Further records were made on 12/9/47 when heads were maturing and the data are given in Table VIII.

TABLE VIII.

VIGOUR MARKING, LEAF COLOUR AND VISUAL SYMPTOMS OF DEFICIENCIES, 12/9/47.

Notation	A	B	C	D	E	F	G	H
Vigour Marking	9	10½	11	11½	10½	11½	8	11
Leaf Colour	Pale green	Pale green	Pale green	Medium green	Medium green	Pale green	Very pale green	Medium green
Visual Symptoms	Slight N and Mg deficiencies	Trace N and Mg deficiencies	Trace N and Mg deficiencies	Trace Mg deficiency	Trace Mg deficiency	Nil	Medium N and Mg deficiencies	Nil

Vigour markings are low in A and G where bulky organic manures only were given. Nitrogen and Mg deficiencies were more marked in these plots than those supplied with inorganic nitrogen. The pale green foliage observed in treatment N.P.K. as potash salts (F), was probably the result of the high chloride level, and the absence of symptoms of Mg deficiency from this plot is noteworthy. The application of magnesium sulphate to treatment H has corrected the symptoms of Mg deficiency.

Yield Results.

Yields were taken for total "heads" cut and also for the marketable "heads". The data have been analysed statistically and are presented in Tables IX and X.

TABLE IX.

TOTAL YIELDS. SHOWING MEAN YIELDS (TONS PER ACRE) AND ORDER OF YIELDS.

Notation	A	B	C	D	E	F	G	H	Mean
Yields (Tons)	7·01	7·55	7·92	8·75	8·03	7·98	6·38	8·31	7·74
Order of Yields	7	6	5	1	3	4	8	2	

S.E. = 0·368 S.D. 5% = 1·12
S.D. 1% = 1·55

At 5% point B, C, D, E, F, H > G.
H, D > A ; D > B.

At 1% point C, D, E, F, H > G ; D > A.

TABLE X.

MARKETABLE HEADS. SHOWING MEAN YIELDS (TONS PER ACRE) AND ORDER OF YIELDS.

Notation	A	B	C	D	E	F	G	H	Mean
Yields (Tons)	6·28	6·68	7·16	7·79	7·36	7·45	5·49	7·38	6·95
Order of Yields	7	6	5	1	4	2	8	3	

S.E. = 0·303 S.D. 5% = 0·92
S.D. 1% = 1·28

At 5% point B, C, D, E, F, H, > G ; D, E, F, H > A ; D > B.
At 1% point C, D, E, F, H > G ; D > A.

The data for total and marketable heads show that bulky organic manures without added nitrogen, viz. A and G, gave low yields. The latter treatment, (straw sludge compost) had the lowest yields and this is in agreement with medium N and Mg deficiencies observed in the plots. Treatment A (farmyard manure) which had higher yields than (G) had slight N and Mg deficiency symptoms. That the depression in yields in plots A and G is mainly due to N and not Mg deficiency is shown by the fact that the last named deficiency was observed in the N.P.K. + hoof (D), which had the highest total and marketable yields.

SUMMARY AND CONCLUSIONS.

1. Potato varieties Majestic, Kerr's Pink and King Edward were grown in 1946 as the eighth crop in rotation, in a manurial trial used to compare the effects of organic and inorganic manures on vegetable crops. During the following year, (1947), Cauliflower var. Majestic was grown.

2. Results are given for vigour, foliage characters including visual symptoms of deficiencies and toxicities, chemical tissue tests and crop weights for potato and cauliflower.

3. In the two crops the manurial treatments were reflected by vigour markings of the plants. Deficiencies of N and Mg were observed in potato and cauliflower and in addition chloride injury was recorded in potato. Nitrogen deficiency was marked when bulky organic manures were not supplemented by a nitrogenous fertiliser and in these instances N deficiency accentuated Mg deficiency. The latter deficiency was absent in the N.P.K. as chloride (F) and N.P.K. sulphate + magnesium sulphate (H) treatments. King Edward was more adversely affected than the other two varieties and defoliated where N and Mg deficiencies occurred.

4. Chemical tissue tests confirmed the visual symptoms of N and Mg deficiency and Cl toxicity. There was a correlation between the nitrate N and Mg status of the plants ; when the first named was low, Mg was usually at the deficiency level. Majestic had higher Mg values than Kerr's Pink and King Edward under similar manurial treatments and this was in accord with the greater susceptibility of the latter two varieties to the deficiency.

5. Nitrogen deficiency was the main factor limiting ware and total yields in potato and cauliflower. Low yields were associated with the use of bulky

organic manures such as farmyard manure or straw sewage sludge without the addition of a nitrogenous fertiliser as a supplement.

Varietal differences in ware yields in potato were in the following ascending order King Edward < Kerr's Pink < Majestic. This was in accord with the susceptibility of the varieties to nitrogen and magnesium deficiencies.

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THE USE OF *ASPERGILLUS NIGER* (M STRAIN) IN THE BIOASSAY OF MAGNESIUM, COPPER, ZINC AND MOLYBDENUM IN SOILS. I.

By D. J. D. NICHOLAS and A. H. FIELDING.

Microbiological methods for the determination of mineral nutrients in soil, using fungi of the genus *Aspergillus*, were introduced by Butkevic (4) and Kosceleckii (6). Other workers have used a variety of fungi : Seidel (17) used *Rhizopus* spp. ; Mehlich *et al* used *Cunninghamella* spp. for the determination of available phosphate, while Niklas and Hirschberger (12) and Simakova and Bouschik (19) employed *Aspergillus* spp. for this purpose. Other organisms used have included bacteria ; *Azotobacter* by Christensen (5), Niklas and Hirshberger (12), Truffaut and Bezssohoff (22) and more recently *Bacterium globiforme* (11) by Nicol. The work has recently been reviewed by Behrens (3).

Mulder (8) has made a thorough investigation of the sensitivity of a number of *Aspergillus* species to Cu and Mg respectively and found that *Aspergillus niger* (M strain) (1, 8) was the most satisfactory. When Cu was withheld from the culture solution inoculated with the fungus, a white vegetative mycelium was formed after five day's incubation whereas the addition of 0·2 μg. Cu per 40 ml. of culture solution (1 part in 200 million) produced a vigorous sporing mycelium with orange yellow spores ; with 0·4 μg. Cu, light grey brown spores ; and with larger additions, 1·0, 1·5 and 2·5 μg. Cu, brown, dark brown and black spores were formed respectively. This range of spore colour could be reproduced and depended on the presence of copper. This method has been successfully applied in the study of " reclamation " disease (*Ontginningsiekte*) in Dutch soils (9) and also by Acock (1) using Cu deficient soils from South and West Australia where " coast disease " and " steely wool " in sheep and a cereal deficiency disease known as " wither tip " are common.

Mulder has also shown that the omission of Mg from the culture solution inhibited spore formation and that the density of spore cover could be related to increasing amounts of the mineral element. Magnesium, although affecting spore formation, did not affect spore colour as did Cu, nevertheless the method has been used in the determination of available Mg in soils (8).

In this paper preliminary results are given on the use of *Aspergillus niger* (M strain) in the bioassay of magnesium and copper in soils. An attempt has also been made to develop satisfactory chemical methods for the elimination

of Zn and Mo from the media using organic reagents e.g. dithizone and 8-hydroxyquinoline, for future work on the bioassay of these micro nutrients in soils. The results show that the *Aspergillus* method can be used in the determination of the available Mg and Cu in soils and that the results compare favourably with those of chemical methods. Special purification procedures are given for the elimination of Cu, Zn and Mo respectively from the media for bioassay of the three micro nutrients in soils.

EXPERIMENTAL.

Bioassay Method for Magnesium.

Mulder's technique has been examined and a number of modifications have been made. The fungus used in all these experiments was *Aspergillus niger* (M strain).

Culture Solution.

The culture solution used for growing the *Aspergillus* was substantially the same as used by Mulder, having the following composition :—

Dextrose A.R.	50 gm.	$FeCl_3 \cdot 6H_2O$	0·02 gm.
KNO_3	5 gm.	$ZnSO_4 \cdot 7H_2O$	0·01 gm.
KH_2PO_4	2·5 gm.	$MnSO_4 \cdot 4H_2O$	0·003 gm.
$Na_2SO_4 \cdot 10H_2O$	1·0 gm.	$Na_2MoO_4 \cdot 2H_2O$	0·0015 gm.
$MgSO_4 \cdot 7H_2O$	1·0 gm.	$CuSO_4 \cdot 5H_2O$	0·001 gm.

These salts were dissolved in a litre of glass distilled water. Although salts in the medium were of the A.R. grade it was found that a mycelium was formed in the omit Mg culture. In view of this KNO_3, KH_2PO_4 and Na_2SO_4 were recrystallised twice from glass distilled water and in this way it was possible to eliminate Mg as was shown by the absence of mycelial growth in the omit Mg culture incorporating these purified salts.

Preparation of a series of Mg standards.

The medium was made up without $MgSO_4$ and then 40 ml. portions were added to a series of 12 litre Pyrex flasks. The Mg standard solutions were then added viz. 0, 25——500 μg. Mg. respectively, in steps of 25 μg. Mg, the flasks were plugged with cotton wool and autoclaved at 120°C at 15 lb. per square inch for 15 minutes. The medium was allowed to cool and each flask inoculated with a single drop of spore suspension of *Aspergillus niger* (M) contained in sterile glass distilled water. The flasks were placed in an incubator for six days at a temperature of 25°C.

Preparation of Soil for Bioassay of Magnesium.

Mulder has recommended the use of sieved air dry soil without previous sterilisation because the *Aspergillus* usually grows quickly and interference from other soil fungi has been negligible. Acock (1) however has encountered serious contamination from other fungi when using the Mulder method for the evaluation of Cu in Australian soils. He suggested partial sterilisation of soils by saturating with 70% alcohol for an hour and warming to evaporate the alcohol before inoculating with the spore suspension. A similar interference from other fungi has been encountered in preliminary experiments described herein and methods were tried to eliminate foreign micro-organisms present in the soil. It is well known that autoclaving and steam sterilisation of soils

may increase the availability of soil nutrients (1) and Mulder has shown that prolonged treatment of soils with organic solvents, e.g. alcohol and acetone may affect the availability of the micro nutrients e.g. Cu.

The methods tried for the sterilisation of the soil were as follows :—

1. *Preheating soil.* 0·5, 1 gm., and 2 gm., portions of normal and soils deficient in Mg respectively were heated in a small air oven at either (a) 200°C for 1 hour (b) 100°C for 1 hour or (c) 60°C for 12 hours. After cooling, each portion was added to 40 ml. of sterile medium free from Mg, in Pyrex flasks. After inoculation with a spore suspension of *Aspergillus niger* the cultures were placed in the incubator at 25°C for six days. Each determination was made in duplicate.

2. *Autoclaving soil with the medium.* Similar quantities of normal and Mg deficient soil respectively were added to flasks containing 40 ml. of culture solution (Mg omitted) and the medium and soil autoclaved at 120°C at 15lb. pressure per square inch for 15 minutes. After cooling, the medium was inoculated and incubated as above.

3. *Alcohol treatment.* Similar quantities of normal and Mg deficient soil respectively were placed on Petri dishes and 0·5 ml. of 70% redistilled ethyl alcohol added per 0·5 gm. of soil and covered over with a lid for one hour. Then the lid was removed and the dish warmed to drive off the alcohol. The soil was then added to the sterile Mg-free medium.

All the above methods were effective in eliminating contaminating fungi except the alcohol treatment which was partially effective.

The maximum difference between normal and soil deficient in Mg was obtained using either preheating at 200°C for 1 hour or autoclaving the soil with the medium. The latter was the most convenient procedure.

The optimum amount of soil required for the bioassay of Mg was 1 gm. for 40 ml. culture solution.

Chemical Method for Exchangeable Magnesium in Soils.

For comparison with the data obtained by bioassay, the following chemical method, described by Peech (13), was used for determining exchangeable Mg in the soils. About 25 gm. of soil was extracted for 15 minutes with 200 ml. of neutral ammonium acetate, filtered into a 250 ml. flask and made up to volume with the extractant. Then 100 ml. of solution was taken in an evaporating dish fitted with a watch glass, evaporated to dryness and then ignited for 15 minutes in the presence of 5 ml. of HNO_3 (conc.) and 1 ml. HCl (conc.). The residue was then treated with 3 ml. of HCl (1 : 1) to dissolve the oxides of Mn and Fe and again taken to dryness and heating continued to dehydrate the silica. The residue was then dissolved in 10 ml. of 0·5 *N*.HNO_3 and 20 ml. of distilled water.

A modification of Weeks and Todd's method for the determination of Ca and Mg in soils was used (24). Iron and aluminium were removed at a pH of 5·3 using 2% 8-hydroxyquinoline in 95% alcohol and then Ca was precipitated as the oxalate using ammonium oxalate. The supernatant liquid was used for the determination of Mg using a 2% 8-hydroxquinoline in 95% re-distilled ethyl alcohol in the presence of ammonia at a pH > 8. The magnesium quinolate so formed was dried and dissolved in 10 ml. 3% ferric chloride in 5% acetic acid. The green ferric quinolate colour so formed was determined by means of the Spekker Absorptiometer using ferric chloride solution in the left cell, a water setting of 1 and Ilford red filters. The effective range is from 0·01 to 0·08 mg. Mg per 10 ml.

Bioassay Methods for Micro Nutrients e.g. Copper, Zinc and Molybdenum.

Copper.

The bioassay of micro-nutrients in soils presents special problems in the purification of the salts, dextrose and water that comprise the culture solution. Distilled water from a tinned copper still may contain as much as 10 μg. Cu per litre or 0·4 μg. Cu per 40 mls. of culture solution and this alone is sufficient to support mycelial growth covered with light brown spores. Double distillation of this water using Pyrex glassware effectively reduced the Cu level to less than 1 μg. per litre or 0·04 μg. Cu per 40 ml. of culture solution. A similar reduction has been noted in the Zn content of the water after double distillation from Pyrex glassware.

The salts that supply the major constituents viz. KNO_3, KH_2PO_4, Na_2SO_4-$10H_2O$ and glucose were purified from traces of micro nutrients using a modification of the Steinberg (21) and Arnon and Stout (2) adsorption methods. The modified method has been described and involved the steaming of a solution of the above salts and dextrose in the presence of 10 gm. $CaCO_3$, 20 ml. of 20% $CaCl_2$ and K_2HPO_4 respectively and 10 gm. $NaHCO_3$ per litre at 100°C. for 15 minutes. This was found to be partially effective in eliminating Cu and Zn but had no effect on the removal of Mo.

Further purification of this solution including dextrose was attempted using 0·5% dithizone in carbon tetrachloride at pH 3 using bromophenol or tropaeolin 00 as an external indicator. At this pH, Cu was preferentially extracted from the solution. The extraction was continued until no more Cu could be detected in the dithizone. The carbon tetrachloride was eliminated from the solution of the major constituents before the addition of the micronutrients. The latter were recrystallised twice from glass distilled water. The first crop of crystals only was used. The ferric chloride was prepared from ferric ammonium sulphate using redistilled HCl saturated with ether. The latter extracts the ferric chloride free from other heavy metals from the media. The following standard series were used 0, 0·25, 0·5, 0·75, 1·0, 2·5, 5 and 10 μg. Cu.

It was found that after using the adsorption technique it was difficult to reproduce a standard growth curve, presumably due to the adsorption of the added Cu by the excess calcium phosphate present, although the pH of the media was brought to 5·5 using redistilled HCl. The adsorption technique was discontinued and the dithizone method adopted but several elutions of the macro-nutrients and glucose solution with dithizone were necessary to eliminate copper. Standards made up using media purified in this way were easily reproducible.

Zinc.

Several methods were tried for the removal of Zn from the major nutrients and dextrose. The adsorption technique proved effective in removing Zn but, as for Cu, it was difficult to reproduce a standard growth curve. Dithizone in carbon tetrachloride when added to a solution of the major nutrients and dextrose buffered to a pH of 9, using bromothymol blue as an external indicator, proved effective in eliminating Zn. Several elutions were necessary for the complete removal of Zn and vigorous shaking of the solution is recommended. The addition of resorcinol solution to the dithizone was not an improvement on dithizone alone in the elimination of Zn. Recrystallised micronutrients were used throughout.

Molybdenum.

This micronutrient was removed from a solution of the major nutrients and dextrose by adding 1 ml. of a 5% solution of 8-hydroxyquinoline in 2*N* acetic acid and buffering to a pH of 7, standing for 24 hours (18). The oxine complex was extracted using ether. Several elutions with ether were necessary to extract the complex completely, otherwise the residual quinoline would chelate and inactivate other micronutrients that were added later. Using approximately 500 ml. of culture solution it was found that a minimum of six extractions with ether was necessary for a satisfactory removal of the oxine complex. Vigorous aeration of the culture solution, using a dustproof aerating apparatus made of pyrex glassware, was necessary to eliminate the last traces of ether from solution. The solution was then autoclaved for 15 mins. at 120°C. The micronutrients were recrystallised twice from glass distilled water.

RESULTS.

Magnesium.

The response of *Aspergillus niger* to the addition of 0,25,50—500 μg. is shown in Fig. 1 and described in Table 1.

TABLE I.

THE GROWTH OF ASPERGILLUS NIGER IN RELATION TO MAGNESIUM CONTENT OF THE CULTURE SOLUTION.

Mg as μg. in 40 ml. culture solution	Description of mycelium and spore formation in *Aspergillus niger*	Designation on Fig. 1.
0	No growth	a.
25	Thin weft of mycelium	
50	Thicker mycelium, with few underdeveloped pale brown spores	b.
75	Thicker mycelium with few scattered pale grey brown spores	
100	Thick mycelium greater number of grey brown spores	c.
150	Thicker mycelium with denser spore cover	
200	Mycelium with noticeable grey black spore cover	d.
250	Spores blacker, dispersed over mycelium	
300	Surface nearly covered with black spores with a few grey areas	e.
400 & 500	Complete black spore cover	f.

The data given in Table I and Plate I show that differences in the growth of the mycelium and spore formation were correlated with increasing amounts of Mg and that this method formed a basis for rapid bioassay of Mg in soils as used by Mulder (9) and Steinberg (21).

Bioassay of Mg in soil. The soils tested were taken from a long term manurial trial at Long Ashton in which the following treatments are represented in triplicate ; N P K, P K(omit N), and N P(omit K). In addition, to block 2, magnesium sulphate was added to the soil to offset symptoms of Mg deficiency which were observed in susceptible crops, viz. potato and cauliflower especially in the P K(omit N) and to a lesser extent in the N P K plots (10).

The results for the bioassay of Mg using 1 gm. of roasted and autoclaved soil respectively and chemical analysis of exchangeable Mg on the air dry soil are given in Table II.

TABLE II.

Comparison Between Bioassay and Chemical Data for Mg in Soils as Percentage Mg in Air Dry Soil.

Treatment	NPK			PK (omit N)			NP (omit K)		
Block	1	2*	3	1	2*	3	1	2*	3
Bioassay									
(a) Roasted 1 hr. at 200°C.	0·006	0·016	0·007	0·005	0·016	0·006	0·006	0·013	0·007
(b) Autoclaved	0·009	0·016	0·006	0·007	0·014	0·007	0·005	0·014	0·008
Chemical Analysis. Exchangeable Magnesium.	0·004	0·014	0·005	0·004	0·014	0·004	0·003	0·015	0·006

* $MgSO_4$ applied to the soil.

The data given in Table II show that the Mg treatment given to block 2 is reflected by the bioassay method and that similar values were obtained whether an autoclaved or heating pre-treatment was given to the soil. There is close agreement between the results of the biological and chemical methods and both show the inadequacy of the Mg values in blocks 1 and 3 irrespective of the NPK treatments.

In Fig. 2 is shown the differences in the growth of *Aspergillus* using soil untreated (blocks 1 or 3) and treated with magnesium sulphate (block 2).

In Tables III and IV are given comparisons between crop performance as determined by visual symptoms (23), and ash analysis of potato and cauliflower, and soil data.

The data for potato given in Table III show that there is good agreement between the incidence of Mg deficiency, chemical data for the plants and the bioassay and chemical results for Mg in the soil in the NPK and PK (omit N) plots. In the NP (omit K) plots however, when potassium is low in the plants the Mg content of the tissues is high irrespective of the application of magnesium sulphate. The bioassay and chemical methods for the soil show a low Mg value for the NP (omit K) plots in blocks 1 and 3. In this instance the soil data are of value in showing a deficiency of magnesium in the presence of K deficiency in the soil which is not shown by plant analysis, due to the interaction of K and Mg within the plants.

In Table IV however, data for cauliflower for the NP (omit K) plots show that visual symptoms and plant analysis are in accord with the bioassay method in showing that magnesium and potassium deficiencies may occur together

TABLE III.

Visual Symptoms, and Ash Analysis of Potato (Majestic) as Compared with Soil Data for Magnesium and Potassium 20/8/46.

Treatments	Block	Visual Symptoms	Plant Analysis		Soil Analysis		
			% Dry Matter		% Air dry soil		
					Bioassay	Chemical (Exchangeable)	
			K_2O	MgO	Mg	K	Mg
NPK	1	Mg deficiency (trace)	4·35	0·55	0·006	0·027	0·004
	2*	Nil	4·72	0·96	0·016	0·025	0·014
	3	Mg deficiency (trace)	4·69	0·52	0·007	0·029	0·005
PK (omit N)	1	Mg deficiency (medium)	5·42	0·40	0·005	0·035	0·004
	2*	Nil	4·15	0·92	0·016	0·030	0·014
	3	Mg deficiency (medium to severe)	6·11	0·25	0·006	0·037	0·004
NP (omit K)	1	K deficiency (severe)	0·63	1·16	0·006	0·003	0·003
	2*	,, ,,	0·86	1·46	0·013	0·005	0·015
	3	,, ,,	0·77	1·06	0·007	0·005	0·006

* Magnesium sulphate applied to the soil at 1 cwt. per acre.

TABLE IV.

Visual Symptoms, and Ash Analysis of Cauliflower as Compared with Soil Data (see Table III) for Magnesium and Potassium, 25/9/46.

Treatment	Block	Visual Symptoms	Plant Analysis	
			% Dry Matter	
			K_2O	MgO
NPK	1	Mg deficiency	5·26	0·22
	2*	,,	4·24	0·32
	3	,,	5·59	0·23
PK (omit N)	1	Mg deficiency	5·02	0·18
	2*	,,	4·02	0·20
	3	,,	5·39	0·25
NP (omit K)	1	K & Mg deficiencies	1·11	0·26
	2*	,,	1·53	0·32
	3	,,	1·69	0·23

* Magnesium sulphate applied to the soil.

Copper.

The following standard series were grown; 0, 0·25, 0·5, 0·75, 1·0 and 2·5 μg of Cu and the descriptions are given in Table V.

TABLE V.

Cu as μg in 40 ml.	Description of spore colour
0	White mycelium, no spores
0·25	Orange yellow spores
0·5	Light brown spores
0·75	Greyish brown spores
1·0	Dark brown spores
2·5	Black spores completely covering the mycelium
5	Black spores completely covering mycelium

The data show good agreement with those of Mulder (8) and Acock (1) and confirm that spore colour could be used as a basis for the determination of available copper in soils.

Soil taken from an alkaline fen near Methwold in Norfolk, was examined for copper using the *Aspergillus* method. The soil is a calcareous peat, high in organic matter with a pH of 7·5. Cereal crops grown in this soil have given poor yields and the addition of copper sulphate at 50 lb. per acre to trial plots in 1946 increased vigour and yields.

During the 1947 season foliage spray treatments incorporating various combinations of dilute solutions (0·25%) of manganese, zinc, copper, nickel and cobalt as sulphates, showed that the copper had the main effect on increased vigour and yields in wheat (15).

The results of the bioassay method for the Methwold soil and comparison with a Long Ashton soil treated with NPK are given in Table VI and are expressed as μg. per gm. of soil.

TABLE VI.

Comparison between Copper in Long Ashton and Methwold Soil as determined by Aspergillus niger (M).

Location	Soil Characters	Bioassay (Cu availability μg. per gm. of soil)		
		No pretreatment of soil	Soil heating for 1 hr. at 100°C.	Soil autoclaved with media
Long Ashton	Calcareous drift overlying Keuper Marl. N.P.K. treatment in long term manurial experiment	Black spores but mycelia and spores of other fungi present	Black spores (no contamination) >5	Black spores (no contamination) >5
Methwold Norfolk	Alkaline fen soil. High in organic matter	Pale brown spores masked by presence of other fungi	Pale brown spores 0·5 to 0·75	Pale brown spores 0·5 to 0·75

The above data show that the Methwold fen is low in available copper as compared with the Long Ashton soil (see fig. 3). The values are within the deficiency levels suggested by Mulder and Acock for Dutch and Australian soils respectively, viz. 0·2 to 1 μg. Cu per gm. of soil as compared with > 2 μg. for normal soil.

When the soil was not pretreated contaminating fungi interfered with the growth of *Aspergillus*. The heating or autoclaved treatment has increased the availabliity of Cu to the fungus but differences between normal and Cu deficient soil was maintained.

Wheat samples taken from this area during 1946 and 1947 were analysed for copper. The results are as follows :—

WHEAT.

Treatment	Cu in p.p.m. dry matter	
	Straw	Ear
Sprayed with water only	4·2	5·7
Sprayed with Mn, Zn, Cu, Ni and Co as sulphates (0·25% strength)	18·2	6·8
Sprayed as above without Cu.	6·8	5·6

Significant differences are evident in the Cu content of the straw of plants sprayed with Cu and those given water only, or micronutrient spray without copper. The differences for the ear values however, are not great.

The values for the straw may be compared with those given by Sjollema (20) for Cu deficient wheat in Holland :—

Copper Content of Wheat (as p.p.m. in dry matter)

	Cu deficient	Healthy
Ear	1·5 to 5	5 to 10
Straw	8·5	9 to 18

The values for untreated wheat straw from Methwold are comparable with values for Cu deficient wheat reported by Sjollema. The ear values however, are higher than for Dutch wheat deficient in Cu but may be near the threshold of deficiency level.

Thus chemical analysis of wheat and the bioassay method are in accord in showing that the Methwold fen soil is lower in available Cu than the Long Ashton soil.

Zinc.

In fig. 4 are given the results of the (1) adsorption technique (2) dithizone method and (3) adsorption and dithizone and resorcinol method for the removal of zinc from the major nutrients and subsequent growth of the fungus. The adsorption method has removed a considerable quantity of zinc but there was sufficient left to support very thin mycelial growth and a sparse spore cover. The dithizone procedure eliminated zinc completely and was more effective

alone than when resorcinol was also included. The reduction in growth was not caused by a fungicidal action, as the control shown in fig. 4a was given the same purification treatment and then 0·01 gm. $ZnSO_4$ was added.

Molybdenum.

The use of 8-hydroxyquinoline for the removal of Mo has been described and was similar to the method used by Scott and Mitchell (18) for the concentration of micronutrients for spectrographic analysis. Chemical analysis showed that 20 μg. Mo present in the culture sulution could be reduced below 0·5 μg. using the purification proceedure. Analysis of the fungus and culture solution showed 21 μg. of Mo in the normal culture whereas none could be detected in the omit Mo culture,

The efficiency of the purification procedure was further proved by a bioligal test. A vigorous sporing mycelium was produced in the culture including Mo but when omitted weak vegetable growth only was recorded. To prove that this effect was caused by Mo deficiency, a solution of recrystallised sodium molybdate, in double glass distilled water, was added containing 10 μg Mo. After 24 hours spores appeared which later covered the previously vegetative mycelium.

The success of this procedure is dependent on the complete removal of the oxine complex and in particular the elimination of the last traces of quinoline, otherwise a fungicidal effect is produced. In all instances the normal culture should be treated in the same way as for the omit Mo.

CONCLUSIONS AND SUMMARY.

In this preliminary paper the use of *Aspergillus niger* (M) for the bioassay of magnesium, copper, zinc and molybdenum have been examined.

The data for magnesium show that the growth of the fungus may be related to increasing amounts of Mg in the culture solution and that when it is absent there is no growth of the mycelium. Recrystallisation of the nutrients from glass distilled water was effective in eliminating Mg from the medium.

Further purification of the nutrients was necessary to eliminate Cu, Zn and Mo. A modification of the adsorption technique as used by Steinberg (21) and Arnon and Stout (2) proved effective in eliminating Cu and Zn but this was improved upon by using dithizone at pH 3 and pH 9 for the further extraction of Cu and Zn respectively. It was found that dithizone in carbon tetrachloride alone was effective in removing Cu and Zn at the differential pH values and that a standard growth series could be reproduced, which was not always possible after the adsorption technique. This was probably due to the presence of excess calcium phosphate in the medium adsorbing the Cu or Zn added and thus affecting the standard growth curve. For Mo another technique using 8-hydroxyquinoline was used for its elimination from the macro nutrients, and chemical analysis of the medium and fungus showed a complete removal of Mo. The diversity of methods used emphasise the complexity of the problems relating to the purification of nutrients from Mg, Cu, Zn or Mo.

The copper series could be assessed using spore colour (pale yellow to black) as an index of quantity of Cu present (8). When Cu was omitted a sterile white mycelium was produced whereas in the absence of Mg or Zn no growth of the fungus occurred.

The pretreatment of soil, which was not included in Mulder's original technique (8) appears to be necessary because of interference from other fungi,

in particular *Mucor* species, as was also found by Acock (1). The method of heating the soil prior to use or autoclaving with the media proved effective and gave similar results. These values although slightly higher than those for untreated soil showed consistent differences for normal and soils deficient in Mg or Cu.

Correlations between the bioassay method and chemical analysis of Mg in soil showed close agreement. It was possible to detect magnesium deficiency in soil in the presence of potash deficiency, which was not shown by chemical analysis of the potato crop due to the interaction of K and Mg within the plants, viz. when K was low, Mg increased in the tissues.

It was also possible to confirm probable Cu deficiency in an alkaline fen soil using the bioassay technique. The values obtained, 0·5 to 0·75 μg. Cu per gm. of soil, may be regarded as a threshold level comparable to those obtained by Mulder (9) and Acock (1) for Dutch and Australian soils respectively, deficient in copper. The deficiency was confirmed by chemical analysis of wheat plants grown in the fen soil, and by responses to dilute copper sprays to the foliage.

ACKNOWLEDGMENTS.

The work was financed out of a special grant provided by the Agricultural Research Council to whom thanks are due. The authors are grateful to Mr. R. W. Marsh for his advice and interest during the course of this investigation.

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Fig. 1.

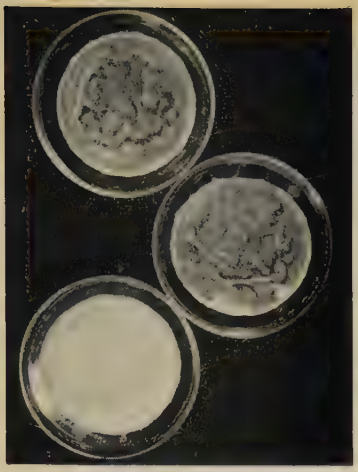

Fig. 2

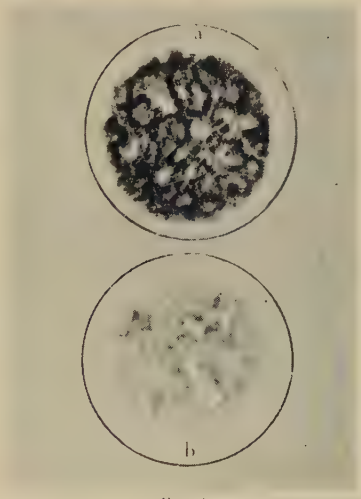

Fig. 3

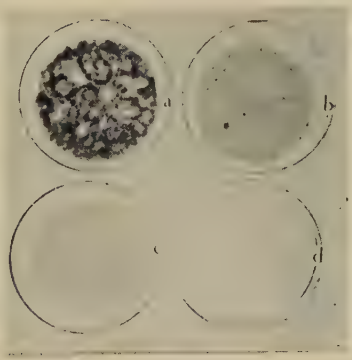

Fig. 4.

EXPLANATION OF PLATE.

Fig. 1. Growth of *Aspergillus niger* after 6 days at 25°C. in culture solutions containing the following concentrations of Mg (in μg. per 40 ml.) : (a) 0, (b) 25, (c) 50, (d) 100, (e) 150, (f) 200.

Fig. 2. Growth of *A. niger* after 6 days at 25°C. in culture solutions containing 1 g. heat-sterilised soil : upper and middle cultures including soil with adequate Mg (N P K and N P treatment, block 2) ; lower culture including soil deficient in Mg (N P treatment, block 1).

Fig. 3. Bioassay of copper in soils, using *A. niger* and culture solutions purified with dithizone at pH3 to extract Cu : (a) growth in culture solution with normal soil, (b) growth in culture solution with Cu-deficient soil.

Fig. 4. Bioassay of zinc with *A. niger*, showing the efficiency of various methods in removing Zn from the culture medium : (a) normal culture, with Zn, (b) Zn removed by adsorption, (c) Zn removed by dithizone and resorcinol, (d) Zn removed by dithizone only.

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A FURTHER EXPERIMENT ON THE USE OF GROWTH-SUBSTANCES TO INHIBIT THE SPROUTING OF STORED POTATOES

By L. C. LUCKWILL.

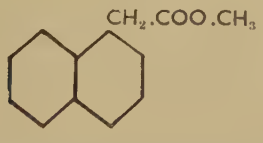
Introduction.

In a previous publication (1) experiments were described which confirmed the effectiveness of methyl-alpha-naphthyl acetate (MANA) in inhibiting the sprouting of stored potatoes, but it was pointed out that, owing to the relatively high cost of autumn treatment, the method was unlikely to find widespread application amongst growers in this country at present. There was thus clearly a need for a substance which, whilst possessing the powerful sprout-suppressing properties of MANA, would be considerably cheaper to manufacture, and it was chiefly with this object in view that the present experiment was undertaken during the season 1946-47.

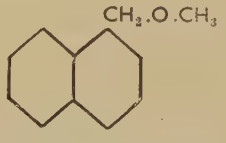
In addition to MANA the two following growth-substances were tested :—*

Methyl-2:4-dichlorophenoxy acetate (M2:4D). This is methyl ester of 2:4D, a growth substance which is widely used as a selective herbicide and which exhibits other manifestations of high physiological activity.

Methyl-alpha-naphthyl-methyl ether (MNME). This compound was known to have been used in Germany during the war for preventing the sprouting of potatoes, but there was little information available as to its effectiveness. Like MANA it is an oily liquid at room temperatures and, as can be seen from their formulae, the two compounds are closely related :—



Methyl-alpha-naphthyl acetate



Methyl-alpha-naphthyl methyl ether.

* I am indebted to Mr. F. E. Smith of Messrs. Pal Chemicals Ltd., for supplies of all three growth substances.

Experimental Methods.

Material. Hand-sorted tubers of the variety Majestic were used for the experiment. Very large and very small tubers, as well as those showing any signs of disease or blemish, were discarded, and every effort was made to obtain a uniform and healthy sample.

Method of storage. The potatoes were stored in half-bushel wooden fruit boxes, lined with greaseproof paper and having nailed-on lids. Sixty tubers, weighing approximately 18 lb. 10 oz. (1/120th ton), were placed in each box and, after treatment, the boxes were stacked in a thick-walled stone barn and covered with straw as a protection against frost.

Method of treating potatoes. Each of the three growth-substances used was made up into a 1% dust, using powdered talc as a " carrier ". The growth substances were first dissolved in acetone and the solution mixed with the necessary quantity of talc. The acetone was then allowed to evaporate off at room temperature and the dry powder was again thoroughly mixed. The potatoes were treated by scattering the requisite quantity of the impregnated dust amongst them as the boxes were being filled.

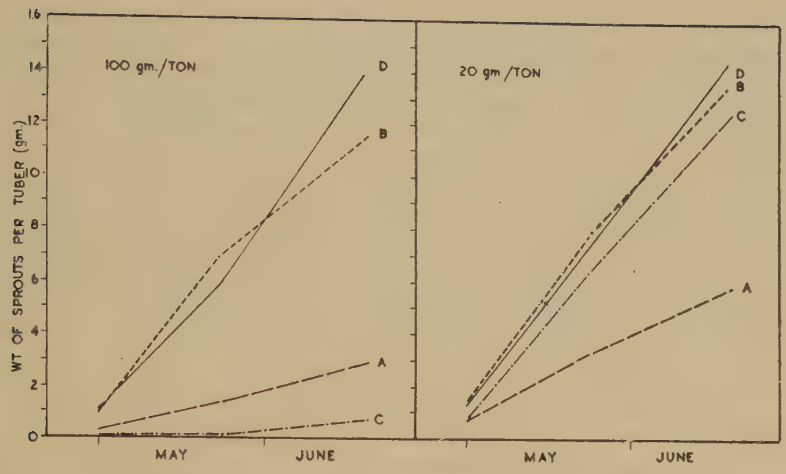
Rates of application. Each growth substance was tested at two rates of application : the high rate corresponded to a dose of 100 gm. of growth-substance (equivalent to 10 kilograms of the 1% dust) per ton of potatoes, and the low rate to 20 gm. per ton. Control series were dusted with talc only at the rate of 10 and 2 kilograms per ton respectively. The treatments were carried out on November 7th, 1946.

Design of experiment. Each combination of the four different treatments and two rates of application was represented by ten boxes of potatoes, and it was planned to sample two boxes on each of five different occasions, in February, March, April, May and June. Owing to the very cold Spring however, the potatoes in the control boxes did not start to sprout until the middle of April and the first sample was not taken until April 30th. Further samples were taken on May 23rd and June 20th, after which the experiment had to be discontinued owing to a severe infestation by the fungus *Rhizoctonia solani*, which destroyed the sprouts in many boxes. At each sampling the total fresh weight of sprouts produced in each box was recorded. In spite of all precautions a few potatoes in some of the boxes on the end of the stack were killed by frost, and the degree of sprouting was therefore expressed as weight of sprouts per healthy tuber rather than as the total weight of sprouts per box. There were no losses due to storage rots.

Results.

Sprout weights. Data on the mean weight of sprouts per tuber on the three different sampling dates are presented in Table I and are shown in graphical form in Figs. 1a and 1b. The data were analysed by the technique of analysis of variance.

It is clear from Fig. 1a that, at the rate of 100gm./ton both MANA (treatment A) and MNME (treatment C) were very effective in reducing the rate of sprouting of the potatoes during May and June. The methylester of 2:4D (treatment B), on the other hand, had little effect, and statistical analysis shows that the weight of sprouts produced by tubers receiving this treatment did not differ significantly from that produced on the control series dusted with talc only (treatment D). Although it appears from the graph that MNME was somewhat more effective than MANA the differences between them do not quite reach the 5% level of significance, and would therefore be expected



Figs. 1*a* (Left) *and* 1*b* (Right). Rate of sprouting of potatoes (var. Majestic) treated with A, methyl α–naphthyl acetate; B, methyl 2-4–dichlorophenoxy acetate; C, methyl α–naphthyl methyl ether; D, talc only.

TABLE I.

Mean Fresh Weight of Sprouts per Tuber on Potato var. Majestic, Stored in Wooden Boxes from November 7th, 1946.

Treatment		Rate of application gm./ton	Date of sampling and mean wt. sprouts per tuber (gm.).								
			30.4.47			23.5.47			20.6.47		
			Box 1	Box 2	Mean	Box 1	Box 2	Mean	Box 1	Box 2	Mean
A	MANA	100	0·29	0·26	0·28	1·71	0·99	1·35	3·02	2·85	2·93
B	M2-4D	100	1·20	0·61	0·90	6·40	7·52	6·96	10·80	12·40	11·60
C	MNME	100	0	0	0	0	0·03	0·02	1·30	0·16	0·73
D	Talc only		1·07	0·85	0·96	7·97	3·89	5·93	14·70	13·05	13·90
A	MANA	20	0·79	0·52	0·66	2·46	4·08	3·27	5·20	6·64	5·92
B	M2-4D	20	1·75	1·15	1·45	7·20	8·53	7·86	14·30	12·90	13·60
C	MNME	20	0·97	0·57	0·77	8·85	3·99	6·42	13·80	11·50	12·60
D	Talc only		1·46	1·16	1·31	7·48	7·41	7·44	16·00	13·20	14·60

to occur by chance more than once in twenty times. Hence, although it can be stated that the methyl ether is at least as effective at this rate of application as MANA, it cannot be definitely asserted that it is more effective.

At the lower rate of application there was no significant difference between the weight of sprouts produced by the controls and those produced by tubers treated with M-2:4D or MNME, MANA being the only substance with any definite effect.

Loss in weight due to sprouting. Apart from wastage due to storage rots, potatoes in store lose weight as the result of sprouting. This is partly due to the utilisation of some of the stored food materials in the tuber in the growth of sprouts, and partly to loss of water. The latter, which is very slight in unsprouted tubers protected by their corky skin, increases rapidly once sprouting begins.

In order to get some estimate of the total loss in weight as a result of sprouting during the storage period, 80 cleaned and numbered tubers were weighed individually and five of these were placed in each of the 16 boxes comprising the last sample. This series of boxes was opened on July 31st, 1947, and each of the numbered tubers, after desprouting, was reweighed, and its percentage loss in weight calculated. The results, given in Table II,

TABLE II.

Loss in Weight of Potatoes var. Majestic, Stored in Wooden Boxes from November 7th, 1946, till July 31st, 1947.

Treatment	Rate of application gm/ton	% loss in weight	
		Mean	S.E.
(A) MANA	100	6·7	2·4
(B) M2 : 4D	100	16·3	6·7
(C) MNME	100	9·6	5·6
(D) Talc only	—	26·6	5·2
(A) MANA	20	12·1	4·3
(B) M2 : 4D	20	18·4	4·2
(C) MNME	20	19·3	6·7
(D) Talc only	—	21·9	4·1

show that the average loss in weight of the untreated potatoes between November and the end of July amounted to 24% of their original weight, whereas those treated with MANA and MNME at 100 gm./ton lost only 6·7 and 9·6% respectively.

Firmness of potatoes. As in previous experiments there was a big difference in the quality of the treated and the untreated potatoes at the end of the storage period. The latter were shrivelled, soft to the touch and tough, whereas those whose sprouting had been suppressed were still quite hard and firm. These observations were confirmed by pressure tests using the form of penetrometer described by Hinton (2). This instrument measures the pressure in lb. required to push a steel plunger of diameter $\frac{1}{2}$ in. with a rounded end a distance of 3/16 in. into the flesh. On July 31st, 20 tubers taken at random from each box were tested with this instrument and the results are given in Table III. As might be expected the firmness of the tubers was found to vary inversely with the percentage loss in weight recorded in Table II.

Effect of treatment on morphology of sprouts. Sprouts produced on potatoes treated with M2:4D were normal in appearance, but marked differences were

noticed between the sprouts which eventually grew on tubers treated with MANA and MNME.

On potatoes treated with MANA the sprouts were few in number, short and thick and evidently developed only from the terminal bud in each " eye ", the lateral buds remaining dormant for a longer period. Where MNME was used however, it was the terminal bud which was the more strongly suppressed, the lateral buds developing first to form clusters of short thin sprouts, quite different in appearance from those produced on the MANA-treated tubers (Fig. 2).

TABLE III.

Penetrometer Readings on Potatoes var. Majestic, Stored till July 31st. Each Figure is a Mean for 20 Tubers Chosen at Random.

Treatment	Rate of application gm/ton	Pressure in lb.		
		Box 1	Box 2	Mean
(A) MANA	100	33·7	37·5	35·6
(B) M2 : 4D	100	26·7	25·4	26·0
(C) MNME	100	37·4	36·5	36·9
(D) Talc only	—	18·6	26·1	22·3
(A) MANA	20	32·9	33·4	33·1
(B) M2 : 4D	20	26·9	30·0	28·4
(C) MNME	20	30·0	24·4	27·2
(D) Talc only	—	21·3	24·9	23·1

Conclusions.

Of the two additional compounds tested this season, one, namely methyl-alpha-naphthyl-methyl ether (MNME) showed considerable activity in suppressing sprouting. Applied in the autumn at the rate of 100 gm. per ton it was at least as effective as MANA, though at the lower rate of 20 gm. per ton it was considerably less effective. Since the cost of this substance is only about half that of MANA it is obviously one which should be tested further with a view to determining the lowest effective rate of application. Should it prove as successful under clamp conditions as it has done in these laboratory trials it might make the anti-sprouting treatment of potatoes in the autumn in this country an economic possibility. Further, since the action of this compound is chiefly on the terminal buds and that of MANA on the lateral buds, suitable combinations of both substances might prove even more effective than either one substance used singly. This possibility of synergistic action should also be investigated.

Summary.

1. An experiment is described in which potatoes stored in wooden boxes were treated in November with three different growth substances applied at two different rates of application. The growth-substances were applied at 1% in a talc " carrier ", and a control series was dusted with talc only.

2. Measurements of sprout weight made at three different dates between April and June showed that methyl-alpha-naphthyl acetate (MANA) and methyl-alpha-naphthyl-methyl ether (MNME) applied at the rate of 100 gm. per ton were both very effective in suppressing sprouting, but the methyl ester of 2:4-dichlorophenoxy acetic acid (M2:4D) had no significant effect. At 20 gm. per ton only MANA had any appreciable effect on the weight of sprouts produced.

3. Potatoes treated with talc only, decreased in weight by 24% between November and July, whereas those treated with MANA and MNME at 100gm./ton lost less than 10%. Pressure tests confirmed that the untreated potatoes were much softer than those whose sprouting had been suppressed.

4. In potatoes treated with MANA the lateral buds of the "eye" were more strongly suppressed than the terminal bud, but when MNME was used the reverse was the case.

5. It is concluded that, should MNME prove as effective under clamp conditions as it has done in laboratory trials, its relative cheapness might make the autumn treatment of potatoes in this country an economic possibility.

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THE EFFECT OF GROWTH SUBSTANCES ON THE STORAGE LIFE OF THE APPLE VARIETIES ALLINGTON PIPPIN AND EDWARD VII.

By L. C. LUCKWILL.

Introduction.

Ethylene compounds are known to hasten the ripening of apples and other fruits. Growth substances, on the other hand, often produce effects which are the reverse of those produced by ethylene (e.g. they prolong dormancy and prevent abscission, whereas ethylene compounds break dormancy and promote abscission), and for this reason it was considered of interest to investigate their effect on the storage life of apples.

During the season 1946–47 a small-scale trial was carried out with three different growth substances on the varieties Allington Pippin and Edward VII held in common storage.

Experimental Material.

The samples of fruit required for the experiment were taken from trees on one of the manurial plots at Long Ashton. *Series A* came from plots receiving a complete NPK fertiliser, whereas *Series B* were gathered from trees receiving N only. Only medium-sized lateral fruits gathered from the sunny side of trees bearing heavy crops were used for the experiment.

Allington Pippin was picked on September 27th. At this time the apples had a good flush of colour, parted readily from the spur, and were free from blemish.

Edward VII was picked on October 7th. The majority of the fruits were still quite green and did not part readily from the spur. Nearly all the

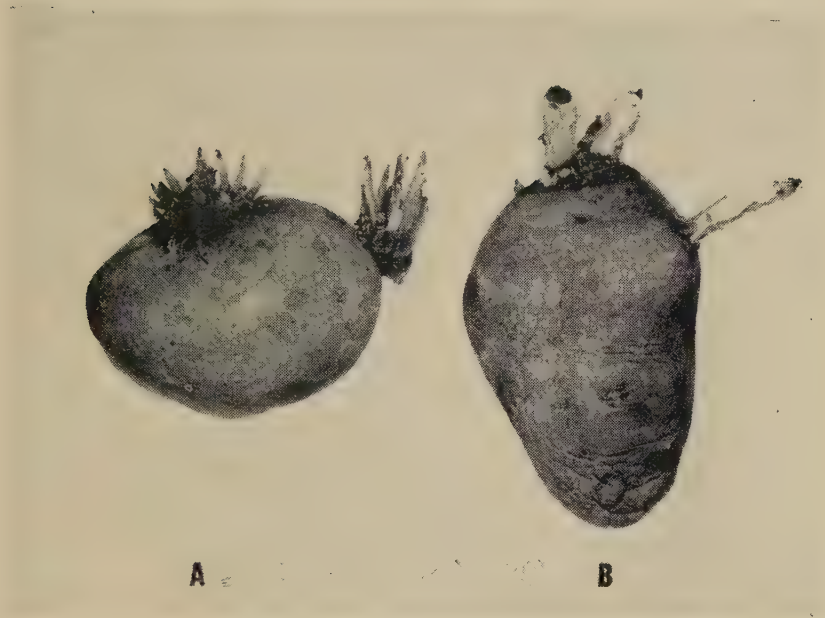

Fig. 2. A : potato stored in the vapour of methyl α–naphthyl-methyl ether showing suppression of terminal bud and growth of lateral buds in each "eye". B : potato stored in the vapour of methyl α–naphthyl acetate. Here the lateral buds have been suppressed more than the terminal bud. Photographed in July.

fruits showed some cracking and flaking around the stem cavity, these defects being more pronounced in the samples gathered from plots receiving N only.

Treatments.

The apples were treated immediately after picking by immersing them in solutions of growth substances in water. After five minutes immersion they were spread out on trays to dry and then placed in storage. The following treatments were applied to samples of 60 fruits of each series of each of the two varieties :—

1. Control—water only.
2. 1-naphthyl-acetic acid (ANA) 10 p.p.m.
3. ,, ,, ,, 50 ,,
4. ,, ,, ,, 100 ,,
5. 2-naphthoxy-acetic acid (BNOA) 10 p.p.m.
6. ,, ,, ,, 50 ,,
7. ,, ,, ,, 100 ,,

In addition to these dipping treatments further samples of fruit from both series A and B were treated by wrapping them in tissue paper impregnated with the methyl ester of 1-naphthyl acetic acid (MANA) at the approximate rate of 8 mgm. per sheet. Control series were wrapped in untreated papers.

TABLE I.

Allington Pippin Examined on 3/1/47.

Treatment	Conc. p.p.m.	% rots		% shrivelled	
		Series A NPK	Series B N	Series A NPK	Series B N
1. Water	—	12	12	77	68
2. ANA	10	13	12	83	83
3. ,,	50	17	8	92	93
4. ,,	100	7	12	94	96
5. BNOA	10	10	5	79	89
6. ,,	50	7	10	96	94
7. ,,	100	10	0	93	93

Results of Dipping Treatments.

Allington Pippin. By October 8th there was a marked increase in colour, but there were no visible differences either between Series A and Series B, or between samples which had been subjected to different dipping treatments. Colour continued to increase until the middle of November, at which time all the fruit was still quite firm, and there were still no perceptible differences between the apples treated with growth substances and those dipped in water only. During December slight shrivelling and wrinkling of the skin of some apples was first noticed, and on January 3rd a count of the number of shrivelled apples in each sample (excluding rots) was made. The results, given below, show that there was appreciably more shrivelling amongst the apples which

had been treated with growth substances, particularly at concentrations of 50 and 100 p.p.m., than amongst the controls.

During the time they were in store the apples were examined at weekly intervals and those showing any signs of rot were removed. The rots were caused almost entirely by attacks of *Botrytis cinerea* and *Gloeosporium perennans*, though a large proportion of otherwise healthy apples developed a certain amount of lenticel spotting (" Allington Spot "). The accumulated percentages of rots in the different samples up till January 3rd are shown in Table I ; none of the variations appear to be correlated either with growth substance treatment or with manurial treatment.

At intervals between January and April samples of fruit were examined for signs of internal flesh breakdown, but none was found, either in the treated or untreated samples.

Edward VII. The apples coloured slowly in storage but, as in the case of the Allingtons, no difference in the rate of colouring of the treated and untreated samples could be detected. The percentage of apples which had

TABLE II.

EDWARD VII, EXAMINED ON 24/3/47.

Treatment	Conc. p.p.m.	% rots		% shrivelled	
		Series A NPK	Series B N	Series A NPK	Series B N
1. Water	—	8	5	49	37
2. ANA	10	8	0	45	54
3. ,,	50	5	7	39	52
4. ,,	100	2	3	49	48
5. BNOA	10	8	3	37	48
6. ,,	50	17	5	44	49
7. ,,	100	8	2	37	40

started to shrivel by the 24th March is shown in Table II. The variability between the different samples is high and although there is some suggestion of an increased rate of shrivelling after treatment with growth substances in the N only series, the differences between treated and control samples is not so well marked as in the Allingtons.

About 70% of the rots were primarily attributable to attack by *Gloeosporium*, 20% to *Botrytis* and 9% to *Diaporthe perniciosa*. There was no definite correlation between the incidence of any of these rots and the treatments applied to the fruit. The apples were kept under observation until June 23rd : by this time there were few sound fruit left, but there were still no signs of internal flesh breakdown, either amongst the treated or control lots.

Results of Wrapping in Impregnated Papers.

In contrast to the dipping treatments, which had comparatively little effect on either Allington Pippin or Edward VII, wrapping the apples in paper impregnated with MANA proved to have a most deleterious influence on

the storage life of both varieties. In the Allingtons this treatment resulted in a very severe attack of Superficial Scald, which, by the time the apples were unwrapped on January 3rd had affected 63% of the fruits. In addition 32% of the apples showed a brown flesh rot which appeared to be associated with the fungus *Diaporthe perniciosa*, the black resting bodies of which developed on the surface of the fruit (*see Fig.* 1). No fruits of the control series wrapped in untreated papers developed either of these troubles.

The effect of MANA on Edward VII was not so marked as on Allington Pippin. Only two fruits were found which showed traces of Scald, but there was a big increase over the controls in the incidence of *Diaporthe* rot when the fruits were examined on March 24th. These results are illustrated in *Fig.* 2 and summarised in Table III.

TABLE III.

Effect of Wrapping Apples in Paper Impregnated with Methyl 1-Naphthyl-Acetate (Mana).

Variety and Date	Condition of fruit.	% of Fruits.			
		Treated MANA		Controls	
		Series A NPK	Series B N	Series A NPK	Series B N
Allington Pippin 3/1/47.	Sound	4	0	91	90
	Scald	71	56	0	0
	Diaporthe rot	29	36	0	0
	Gloeosporium rot	14	5	5	5
	Botrytis rot	2	0	4	5
	Other rots	4	5	0	0
Edward VII 24/3/47	Sound	64	63	80	87
	Scald	0	4	0	0
	Diaporthe rot	19	23	4	2
	Gloeosporium rot	17	10	14	9
	Botrytis rot	0	0	2	2
	Other rots	0	0	0	0

DISCUSSION.

The results of this experiment do not offer any grounds for supposing that growth substances may be of value for prolonging the storage life of apples: on the contrary, dipping the apples in solutions of ANA or BNOA at concentrations of 50 and 100 p.p.m. seemed to have some effect in hastening maturity, especially in Allington Pippin.

Very similar results have recently been obtained by Stuivenberg working with the variety Starapple in cold storage (1). By March 17th he found that those fruits treated with ANA at concentrations of 50 and 100 p.p.m. were somewhat riper, and those treated with higher concentrations of the same substance (140 and 200 p.p.m.) were quite obviously riper than the untreated fruits. Mitchell and Marth (2) and Southwick (3) noted that growth substances in relatively high concentrations tend to hasten the ripening of detached fruits, and other American workers have demonstrated that ANA applied at 10 p.p.m. as a pre-harvest spray hastens maturity of summer varieties of apple, but is without direct effect on the mid-season and late varieties (4).

From these results there seems little doubt that, with most varieties, treatment with growth substances either before or after picking tends to hasten ripening, but that usually the effect is only appreciable when the concentration exceeds 100 p.p.m. Early varieties seem to be much more susceptible than later ones, which possibly accounts for the more marked response of Allington Pippin as compared with Edward VII.

None of the dipping treatments seemed to have any effect on the spread of storage rots, but wrapping the apples in papers impregnated with the methyl ester of ANA led to an extremely severe attack by *Diaporthe perniciosa* on both varieties. In addition the Allingtons developed severe storage Scald, a result which is not in accord with the work of Schomer *et al.* in America (5) who found that treatments with ANA over a wide range of concentrations were all effective in reducing Scald. The lack of agreement between the present results and those of Schomer is probably due to the fact that the methyl ester of ANA, and not the acid itself was used. In this connection it is interesting to note that Brooks (6) has attributed Scald to an accumulation of natural esters in the surface layers of the fruit and in the surrounding atmosphere, and was able to produce typical apple Scald within a few days by exposing the fruit to the vapour of ethyl acetate, ethyl malate, ethyl butyrate and other esters. It would seem therefore that the development of Scald on the Allingtons in this experiment might be due to a similar cause, and that it was probably not a direct effect of the growth substance itself.

SUMMARY.

1. Uniform samples of Allington Pippin and Edward VII apples were treated after picking by dipping them in solutions of 1-naphthyl-acetic acid and 2-naphthoxy-acetic acid at concentrations of 10, 50 and 100 p.p.m. They were then held in common storage and observations were made to determine the effect of these treatments on the storage life.

2. The only observable effect of the dipping treatments was a slightly increased rate of shrivelling in the Allington Pippins, as compared with control samples dipped in water only.

3. Wrapping the apples in paper impregnated with the methyl ester of 1-naphthyl-acetic acid had a most deleterious effect on the storage life of both varieties, a large proportion of the apples developing a brown flesh rot which appeared to be associated with the fungus *Diaporthe perniciosa*. In addition the Allington Pippins developed extremely severe storage Scald.

4. It is concluded that growth substances are likely to be of little value in the storage of fruits.

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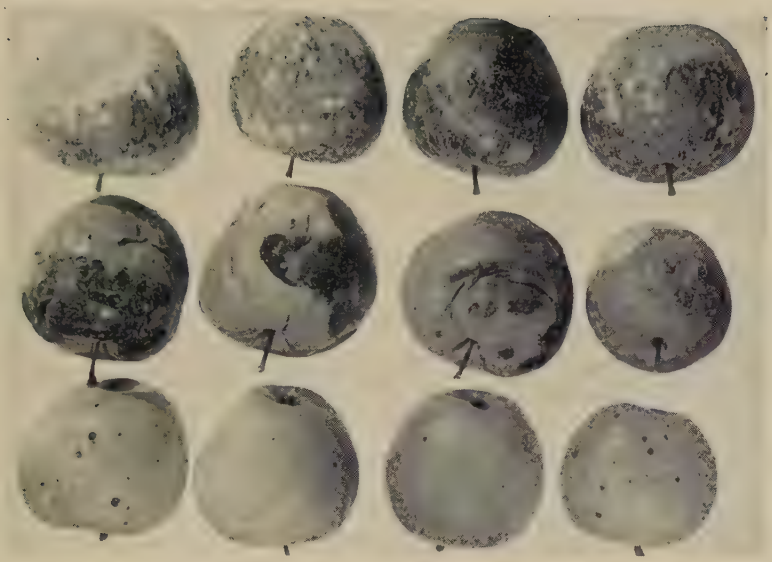


Fig 1. Allington Pippin, 6th January, 1947: lower 4 fruits—controls wrapped in ordinary paper—some 'Allington spot'; middle 4 fruits—wrapped in MANA-impregnated paper—flesh rot with *Diaporthe*; upper 4 fruits—wrapped in MANA-impregnated paper—severe scald.

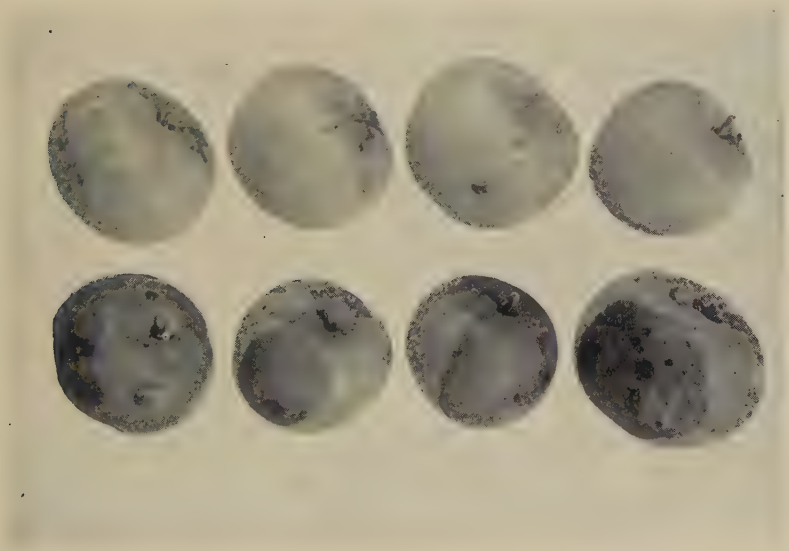


Fig. 2. Edward VII, 8th January, 1947: above, 4 control fruits; below, 4 fruits wrapped in MANA-impregnated paper showing various stages of flesh rot with *Diaporthe*.

THE QUALITATIVE EXAMINATION OF INSECTICIDAL PROPERTIES.

PROGRESS REPORT—1947.

By S. H. BENNETT and H. MARTIN.

The range of compounds reputed to be insecticidal has been so enlarged by wartime and recent academic and industrial research that rapid qualitative methods of assessment are necessary for the selection of those worth further study. The more important of these developments are the work on chlorinated hydrocarbons by commercial interests in the United States and the work on phosphorus compounds by Schrader, Kükenthal and their colleagues in Germany (see Martin and Shaw, 1947 ; Schrader, 1947). An outstanding discovery of the latter workers is that some compounds, when watered on soil in which plants are growing are able to confer systemic insecticidal properties to those plants. Although the compounds so far known to share this property are highly poisonous and render the treated plants toxic to man and stock, the phenomenon is of unusual academic interest. It was therefore considered advisable to record the results of preliminary work on these compounds and to include other points of interest which arose during the routine testing of other reputed insecticides.

CHLORINATED HYDROCARBONS

As Stomach Poisons.

In the 1944 Report (Martin and Wain, 1945) a few trials were recorded of a mixture of isomers of benzene hexachloride (hexachloro*cyclo*hexane) isolated from a proprietary product. Through the courtesy of I.C.I. Ltd., samples of the individual isomers have now been received with which the trials have been repeated.

Larvae of *Mamestra brassicae* were fed daily until death or pupation with a cabbage leaf sandwich containing a known amount of the isomer. The amounts eaten, adjusted in direct proportion to a larval weight of 0.5 g., were :—

α-isomer : two larvae survived 2.6 and 5.2 mg. resp.

β-isomer : five larvae survived, a mean of 7.8 ± 1.2 mg.

γ-isomer : six larvae died, having eaten 0.17 ± 0.061 mg. each.

Δ-isomer : two larvae survived 1.2 ; 1.7 mg. resp., three larvae were affected after eating 1.4, 1.4, 0.6 mg. resp.

The outstanding toxicity which the gamma isomer shows as a stomach poison is in line with its contact insecticidal properties (see e.g. Slade, 1945). With these samples no differential effect dependent on instar age was observed of the type recorded earlier for the mixture of isomers (Martin and Wain, 1945).

As it has previously been shown that the sandwich method may give an exaggerated lethal dose because the larva may eat more than enough to kill it before it ceases to feed, the tests with the gamma isomer were continued with sandwiches containing smaller doses. In the above tests the daily dose used was 0.25 mg., the results with lower doses are included in Table I.

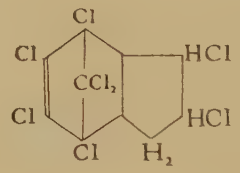
TABLE I.

GAMMA ISOMER OF BENZENEHEXACHLORIDE: VARIATION OF LETHAL DOSE WITH AMOUNT FED.

Daily dose	No. of larvae	Mean amount eaten	Fate of larvae
0·25 mg.	6	0·17 ± 0·061 mg.	Died
0·125 mg.	7	0·10 ± 0·024 mg.	Died
0·025 mg.	2	0·20 ± 0·000 mg.	Died
	8	0·145 ± 0·025 mg.	Survived

From these results it would appear that the gamma isomer is not a cumulative poison for, as the daily intake is lowered, the toxic dose is increased. It would appear either that there is an incomplete adsorption permitting part to be lost in the excreta or that the larvae fed with a sub-lethal dose acquire a toleration to the insecticide. Whatever the cause of the inversion of the toxicity curve it adds to the difficulties given in previous reports and which have to be overcome if the sandwich method is to be made the basis of quantitative bioassay.

Other chlorinated hydrocarbons said to be insecticidal include the chlorinated dicyclopentadiene $C_{10}H_6Cl_8$, reported by Kearns, Ingle and Metcalf (1945), and a chlorinated camphene of approximate formula $C_{10}H_{10}Cl_8$, described under the name 'Toxaphene' by Parker and Beacher (1947). The former compound, known by the trade names 'Velsicol 1068' and 'Octa-Klor', has been christened 'Chlordane' by the U.S. Department of Agriculture and has the structure:



Both compounds conform to the hypothesis advanced in previous reports (Martin and Wain, 1945) that ability to release hydrogen chloride is one required for insecticidal properties in such compounds. Although primarily contact insecticides, they were included in sandwich tests on larvae of *M. brassicae*. Commercial samples of 'Velsicol 1068' (90% agricultural grade), 'Toxaphene' and of 'Geigy D.D.T.' were compared and the mean lethal doses are given in Table II.

TABLE II.

CHLORINATED HYDROCARBONS AS STOMACH POISONS.

Insecticide	Sandwich containing			
	0·50 mg.		0·25 mg.	
	No. of larvae	Lethal dose (mg.)	No. of larvae	Lethal dose (mg.)
Velsicol 1068	4	0·60 ± 0·052	4	0·70 ± 0·022
Toxaphene	5	0·74 ± 0·128	4	0·18 ± 0·042
D.D.T.	–	—	6	0·12 ± 0·014

Unlike D.D.T. which induces a rapid unco-ordinated 'jitters' in the affected larvae, both Velsicol and Toxaphene cause slow ataxic and exaggerated movements.

ORGANIC PHOSPHORUS COMPOUNDS.

Hexaethyl Tetraphosphate.

During the war the shortage of nicotine in Germany was remedied by the use of a substitute "Bladan" discovered by Schrader (1947) and marketed by the I.G. combine. The effective component of this product was a condensation product of phosphorus oxychloride and ethyl phosphate of composition corresponding to hexaethyl tetraphosphate. This compound is soluble in water but, in aqueous solution, is rapidly hydrolysed to non-poisonous and non-insecticidal products. Through the courtesy of Messrs. Albright and Wilson Ltd., two samples of the phosphate were obtained, one (R 6844) prepared by Schrader's method, the second (R 6845) by a method originating from Messrs. Albright and Wilson's laboratories. A third sample was kindly supplied by Messrs. Pal Chemicals Ltd., and this sample, which arrived in a glass stoppered bottle with a cracked neck, was purposely kept in this bottle for six months before testing to see whether it had suffered decomposition through storage in a non-airtight bottle.

Because little is as yet known of the chemistry of the condensation product, the main object of the insecticidal tests was to confirm that the two samples produced by different methods were similar and, for this purpose, stability in aqueous media seemed a good criterion. Therefore although the products are intended primarily as direct contact insecticides they were examined by methods more suited for protective contact insecticides and for stomach poisons because differences in speed of hydrolysis should be better shown by these techniques.

As Protective Contact Insecticides.

The insects are placed on filter paper impregnated with the compound under test and the number affected is counted at intervals.

(1) *Calandra granaria* : 9 cm. No. 50 Whatman filter papers were treated with 0.5 ml. solutions of the hexaethyl tetraphosphate samples dissolved at 10% in acetone, in water, or in aqueous acetone (1:1 by volume). These solutions were prepared either 1 hour or seven days before use and 20 min., was allowed for the evaporation of solvent from the paper before the weevils were added. The number of weevils paralysed 18 hr. and killed after 42 and 70 hr. exposure were counted with the results given in Table III.

From these results it will be seen that the 7 day old phosphate solutions in aqueous acetone and in water have lost their insecticidal properties and indeed the figures for paralysis after 18 hr. exposure indicate some loss of toxicity in both the 10% water and aqueous acetone solution within 20 min. of preparation. No differences are shown between the three samples judged by the results with solutions 1 hr. old.

(2) *Woodlice.* In a variant of the *Calandra* test, woodlice were used, a test designed primarily to detect differences in rate of hydrolysis. One of the following : 0·5 ml. of 10% acetone, acetone-water (1:1 by vol.) or aqueous solution was pipetted on to 9 cm. Whatman No. 4 filter paper discs, the discs being allowed 2 hr. to dry before woodlice were placed on them. The number of woodlice surviving 28 hr. exposure is given in Table IV as a fraction of the number tested, most tests being made in duplicate.

TABLE III.

Toxicity of Various Samples of Hexaethyl Tetraphosphate to Calandra Granaria.

Solvent	Sample	Solution 1 hr. old			Solution 7 days old		
		18 hr. % paralysed	42 hr. % kill	70 hr. % kill	18 hr. % paralysed	42 hr. % kill	70 hr. % kill
Acetone	R 6844	97·5	42	78	97·5	51	90
	R 6845	94·5	44	72	97·5	57	90
	Pal	97·5	41	77	95	49	89
Acetone/water	R 6844	70·5	42	73	0	0	0
	R 6845	57·5	47	77	0	0	0
	Pal	49·0	47	68	0	0	0
Water	R 6844	60·0	39	75	0	0	0
	R 6845	59·0	35	70	0	0	0
	Pal	59·0	21	80	0	0	0
	Control	—	0	0	—	0	0

TABLE IV.

Toxicity of Various Samples of Hexaethyl Tetraphosphate to Woodlice.

Solvent	Sample	Age of Solutions		
		2 hr.	24 hr.	6 days
Acetone	R 6844	0/10 : 0/10*	2/10 : 0/10	0/9 : 0/8
	R 6845	0/10 : 0/10	0/10 : 0/10	0/10 : —
	Pal	0/10 : 0/10	— —	0/9 : 0/8
	Nil	9/10 : 6/10	8/10 : 8/10	8/10 : —
Acetone/water	R 6844	0/10 : 0/10	0/10 : —	5/9 : —
	R 6845	0/10 : 0/10	0/10 : 0/10	5/10 : 3/10
	Pal	0/10 : 0/10	1/10 : 0/10	4/7 : —
Water	R 6844	0/10 : 0/10	0/10 : —	5/10 : 0/3
	R 6845	0/10 : 0/10	0/10 : —	5/10 : —
	Pal	0/10 : 1/10	2/10 : —	2/8 : —
	Nil	10/10 : 10/10	8/10 : 8/10	10/10 : —

* 0/10 None of the woodlice survived.

Even the 6 days old aqueous solutions of the phosphate show a degree of toxicity but no differences between sample R 6844 and 6845 are apparent. The only survivals in the tests with the 2 hr. and 24 hr. old solutions are with the Pal sample, a suggestion that the sample had slightly deteriorated under poor storage conditions.

As Stomach Poisons.

If hexaethyl tetraphosphate undergoes hydrolysis in the insect gut, differences in speed of hydrolysis of the various samples might be revealed by the sandwich method. As all the larvae of *M. brassicae* fed with sandwiches containing 0·025 ml. of the ester died within three days after eating little of the baits, lower doses were tested using 10% solutions of the phosphate in acetone or in acetone-water (1 : 1 by vol.), the solvent being allowed to

evaporate before the sandwich was completed. At this daily dose of 0·0025 ml. of the ester all but one of the larvae fed on sandwiches made with the freshly prepared acetone solutions survived and the amounts eaten, adjusted to a larval weight of 0·5 g. were :

Sample 6844 :	6·6 :	16·0 :	3·5 :	8·0 mg.
„ 6845	8·9 :	(died) :	7·6 :	7·7 mg.
„ Pal	7·5 :	13·6 :	5·7 :	11·7 mg.

Similarly when fed with bait prepared from the acetone-water solutions, only one of the larvae died but the amount of feeding was greatly reduced, five of the caterpillars refusing to eat their sandwich. The doses taken were :

Sample 6844	0·0 :	7·0 :	16·0 :	0·0 mg.
„ 6845	11·6 :	0·0 :	7·5 mg :	(died).
„ Pal	0·0 :	5·6 :	8·4 :	0·0 mg.

Again no differences between the three samples are revealed but it would seem that the hydrolytic products, presumably present in the aqueous acetone solutions, are more repellent to the larvae than the original ester.

Diethyl p-Nitrophenyl Thiophosphate (E 605).

As the instability of hexaethyl tetraphosphate is enhanced by alkali, the ester is unsuitable for use with alkaline spray materials such as lime sulphur. Schrader devoted much time to the discovery of a " lime-stable Bladan," and one of the most promising compounds he reported (Schrader, 1947 ; Martin & Shaw, 1947) is diethyl *p*-nitrophenyl thiophosphate,

$$p\text{-}NO_2.C_6H_4O.PS.(OC_2H_5)_2,$$

to which he gave the code number E 605. A sample of the crude ester made in Schrader's laboratory (Sample A) was compared to one made in this country by Messrs. Albright and Wilson, Ltd. (Sample B).

A quantitative examination of the two samples as protective contact insecticides against *C. granaria* will be published elsewhere by Stringer but trials of the samples as stomach poisons against *M. brassicae* may be recorded here.

Cabbage moth caterpillars fed with sandwiches containing 0·05 mg. E 605 died within 20 hr. usually before they had eaten all the bait. The poison caused intense convulsions with much ejection of liquid and discolouration of the body segments. At this rate of feeding the mean lethal dose, for Sample A, was 0·036 ± 0·006 mg. and, for Sample B, 0·036 ± 0·005 mg., figures which show no difference in toxicity between the two samples and prove that E 605 is an extremely potent stomach poison for, under like conditions, the lethal doses of D.D.T. and of the gamma isomer of benzene hexachloride are of the order of 0·1 mg.

SYSTEMIC INSECTICIDES

Many attempts have been made in the past to find chemicals which will, when taken up by plants, protect them from insect attack. The most promising of the chemicals, until recently, were compounds of selenium, work which originated in the observation of Hurd-Karrer and Poos (1936) that wheat growing on seleniferous soils was not attacked by aphides. Since that time many applications of this property of selenium compounds have been made, one of the latest being for the control of chrysanthemum eelworm (Dimock,

1944). The ability of plants to take up selenium was known, for the so-called alkali disease of stock in certain areas of the Middle West was traced to selenium poisoning by fodder crops grown on seleniferous soil. Nor is it surprising that plants can take up selenium compounds for this element is closely related chemically to sulphur, an element essential to plant growth. Hurd-Karrer (1937) for instance showed a parallel variation in the rates of absorption of the two elements by different plants and she also found that the sulphur/selenium ratio of the plant tissue rises as the sulphur content of the seleniferous soil is increased. It may therefore be assumed that selenium can replace sulphur in the plant's metabolism and that the selenium compounds are absorbed and translocated in selenium-tolerant plants in the same way as are the sulphur compounds. It is less easy to visualise a mechanism for the absorption and translocation of a bulky insecticidal molecule foreign to the plant. Yet there was evidence that the movement of such a molecule within the plant is possible for Fulton and Mason (1937) found that if derris is applied to the first true leaves of bean plants, the leaves formed subsequently are less readily attacked by larvae of the Mexican bean beetle than are similar leaves of untreated plants. But this experiment does not appear to have been repeated or extended and the claims of Schrader (1947) that certain of his insecticides were capable of absorption by plants which thereby became systemically insecticidal seemed almost incredible.

Schrader found this property among widely separated types of compound, the most effective being, on the one hand, certain derivatives of fluoroethyl alcohol and, on the other hand, certain alkylamino-phosphorus compounds. Samples of the compounds given as most effective by Schrader were unfortunately not available, but preliminary experiments were made possible by Dr. B. C. Saunders who has described the preparation and properties of compounds closely allied to those discovered by Schrader (McCombie and Saunders, 1946). The particular compound used was bis (2-fluoroethoxy) methane, $CH_2(OCH_2CH_2F)_2$, a water-white liquid slightly soluble in water.

The first trial was on groundsel plants potted in 3″ pots and watered with 10 ml. of a 1% aqueous solution of the compound. The following day nearly fully grown larvae of the Cinnabar moth (*Callimorpha jacobaeae* L.) were placed on the plants and on those in untreated pots placed alongside. On the latter control plants the larvae fed normally and in sixteen hours had eaten nearly all the leaf laminae. On the treated plants however, there was little feeding and most of the larvae had dropped to the soil and were giving a peculiar side-to-side body twitching with little co-ordinated movement. Some of the larvae were hanging from the treated plants by the abdominal claspers. Larvae placed on other plants 18 hours after watering with 10 ml. of a 1·0% solution of the compound had all fallen from the plants within 24 hours and, although some were showing the twitching movement mentioned above, most were moribund.

Having confirmed the existence of the systemic effect, further trials have been made for the purpose of determining the order of the amount required to produce the effect, firstly against aphides and secondly against leaf-eating caterpillars.

Bean aphis. 8″ flower pots containing 5 or 6 tick bean plants about 2 ft. high were used, the pots being watered with various amounts of 1% aqueous solution of the fluoroethoxymethane. After treatment the plants, which were growing in an unheated glass house, were infested with *Aphis fabae* by placing a leaf or sprig of bean heavily infested with the aphid in the axil of a leaf about

half way up the plant. As the infested sprig withered, the aphides moved to the growing plant and usually wandered to the growing point where an infestation built up. The results are assembled in Table V, which includes the degree of infestation of the plants on 12/7/47 five days after attempted infestation.

TABLE V.

INFESTATION OF TREATED BEANS BY *A. fabae*.

Treatment 1% $CH_2(OC_2H_4F)_2$ per pot	Date of treatment	Degree of infestation
100 ml. + 50 ml. + 50 ml.	30/6/47, 3/7/47, 8/7/47	Nil (three pots).
100 ml. + 50 ml.	30/6/47, 3/7/47	Nil on one pot, almost nil on second and very slight on third
100 ml.	30/6/47	Nil on one pot, other two almost free
10 ml. + 10 ml. + 10 ml.	30/6/47, 3/7/47, 8/7/47	Very slight infestation on all plants
10 ml. + 10 ml.	30/6/47, 3/7/47	Two pots practically free and one slightly infested
10 ml.	30/6/47	Slight to moderate infestation on three pots, a number of dead aphides on one.
Nil	—	Slight infestation on two pots, moderate on third and heavy on fourth, but infestation rapidly thinning.

In a parallel experiment, recorded in Table VI, the transfers of aphis infested material were made on 5/7/47 and the degree of infestation recorded four days later.

TABLE VI.

INFESTATION OF TREATED BEANS BY *A. fabae*.

Treatment 1% $CH_2(OC_2H_4F)_2$ per pot	Date of Treatment	Degree of infestation
100 ml. + 50 ml.	30/6/47, 3/7/47	Slight with many dead aphides on upper surface of leaves
100 ml.	30/6/47	Only a few aphids feeding, no young aphides but many dead
10 ml. + 10 ml.	30/6/47, 3/7/47	Slight infestation
Nil	—	Infestation building up with many young aphides present

In other experiments bean plants already infested with *A. fabae* were watered with even smaller amounts, namely 5 ml. and 10 ml. of 1% fluoroethoxymethane. When examined three days later the aphid population on the treated plant was obviously less than on the control plant and dead aphides of all stages of growth were found on the upper surfaces of the lower leaves of the treated plants.

Although environmental conditions did not favour the rapid development of heavy aphid infestations, the systemic effect of the fluoroethoxymethane was clearly evident even at such low dosages as 0·05 ml. per 8″ pot.

Lepidopterous larvae. 10″ pots each containing a cauliflower plant, just beginning to show curd formation, were watered with various amounts of the fluoroethoxymethane. In one series the plants were left outdoors to be naturally infested. The untreated controls became attacked by larva of *Pionea forficalis*, *Pieris brassicae* and *P. rapae*, *Plutella maculipennis* and *M. brassicae* but all the treated plants, including those receiving only 0·1 g. of the insecticide, were clearly less damaged than the untreated.

Similar plants brought into the glasshouse and treated with 50 ml. of 1% fluoroethoxymethane on 29/7/47 remained free from damage by *P. brassicae* and *P. rapae* until 21/8/47 though the adjacent untreated plants were heavily infested. Eggs of both species were freely laid on the treated plants and, although egg hatching was not apparently affected, the larvae died presumably after eating a trace of the leaf tissue. Plants treated with only 10 ml. of the 1% solution remained almost free from attack for a fortnight. An attempt was made to determine the degree of toxicity of leaves of the treated plants to cabbage moth larvae but the caterpillars refused to eat discs cut from the treated leaves.

In laboratory tests designed primarily to establish that the insecticidal effect was not a fumigant action, the petioles of cabbage leaves were inserted in 3″ × 1″ specimen tubes containing water or a 1% aqueous solution of the fluoroethoxymethane. The specimen tubes were then placed in a beaker containing the insecticide solution or water respectively so that each leaf was over both insecticide and water. Young larvae of *P. brassicae* were then transferred to the leaves and only those leaves with their petioles in water were eaten by the caterpillars.

Calandra Granaria.

Wheat sown in 10″ flower pots was watered at the flowering stage with various amounts of 1% fluoroethoxymethane solution or with 0·1% solution of anhydrous sodium selenate. After due protection from birds, the ears were harvested at maturity and the grain infested with adult grain weevils. Four weeks after the adults were removed and counted, the grain then being stored for a further four weeks when the number of adult weevils present was determined. The treatments and counts are given in Table VII. From this table it will be seen that neither the selenate nor the fluoroethoxymethane treatments have given grain directly toxic to the adult weevils.

But no infestation has been built up in the selenate-treated wheat and, although the grain obtained from the plants receiving the heavier amounts of selenate was much inferior in size and quality to that from other treatments, it would seem that the factor responsible for the absence of eggs or larvae in this wheat is the selenate treatment. If this conclusion is correct some fascinating corollaries follow, for it would indicate that certain sulphur-containing proteins or vitamins are uniquely concerned in the reproduction

process which becomes deranged if the analogous selenium compounds are present.

The non-persistence of the systemic toxicity induced by the fluoroethoxymethane suggests that such compounds would be of wider practical use than the persistently poisonous selenium treatment. But clearly it would be wiser to use, for such practical purposes, a systemic insecticide not containing the dangerous element fluorine.

TABLE VII.

Infestation by C. Granaria of Grain from Treated Wheat.

Treatment				Infestation		
				at 4 weeks		at 8 weeks
Insecticide	Vol. ml.	No. of Applications	No. adults added	No. dead	% kill (con.)	No. adults
	10	1	56	1	0	429
	50	1	50	2	0	124
0·1% Na_2SeO_4	50	2	50	1	0	75
	50	3	61	5	0	0
	100	1	72	0	0	139
	10	1	50	1	0	437
1·0% $CH_2(OC_2H_4F)_2$	10	2	51	7	5	174
	100	1	49	2	0	398
	100	2	50	2	0	265
Nil	—	—	44	4	—	344

SUMMARY.

1. The high order of toxicity of the gamma isomer of benzene hexachloride as a stomach poison is shown by the sandwich method using larvae of *Mamestra brassicae*; the insecticide is not a cumulative poison.

2. The chlorinated dicyclopentadiene and terpene known respectively as ' Chlordane ' and ' Toxaphene ' are effective stomach poisons to *M. brassicae* and conform to the hypothesis that ability to release hydrogen chloride is one requirement for insecticidal properties in such compounds. They cause slow ataxic movements in affected larvae in contrast to the rapid unco-ordinated D.D.T. " jitters."

3. *Para*-nitrophenyl diethyl thiophosphate is an extremely potent stomach poison to *M. brassicae*; no differences in toxicity were detected between samples of German and of British origin.

4. Three different samples of hexaethyl tetraphosphate were examined by the sandwich method and as contact insecticides by the filter paper method for differences in susceptibility to hydrolysis. No differences were observed but the hydrolytic products appear to be repellent to larvae of *M. brassicae.*

5. Preliminary experiments have confirmed that plants watered with dilute aqueous solutions of bis(β-fluoroethoxy)methane acquire systemic insecticidal properties. The effect is rapidly shown throughout the plant but the systemic toxicity is less persistent than that induced by sodium selenate.

ACKNOWLEDGMENTS.

We are indebted to Mr. A. Stringer for permission to include data obtained by him using *C. granaria* as test insect.

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A NEWLY RECORDED BARK DISEASE OF APPLE

By S. H. CROWDY and J. E. FORSHAW (Advisory Officer in Horticulture, National Agricultural Advisory Service).

INTRODUCTION.

During recent years a bark disease of apple, not previously described, has been reported from South Somerset. The disease was first noticed by J. E. Forshaw about 15 years ago in an orchard at Stembridge near Kingsbury Episcopi, as a swelling on the stem of a variety of apple known locally as " White Tom Putt ". The affected tree, which was somewhat stunted, was at that date, the only example found of this type of disorder. However, the disease has subsequently spread in the original orchard and has also been recorded in several other orchards in the same district. The damage resulting on some of the trees infected has been severe.

Symptoms.

As far as can be judged at present the earliest symptom of the disease is the appearance of a small patch on the branch in which the bark looks dry and cracked (Plate Fig. 1,A). From this point the roughened area spreads round the branch and the bark becomes more deeply fissured and folded ; at the same

Explanation of Plate

Illustrations of a branch of Bramley's Seedling showing infections. ($\times \frac{1}{3}$).

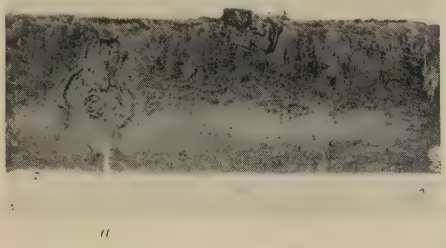


Fig. 1. Smooth normal bark showing a little scaling : (*a*) Early stage of the disease.

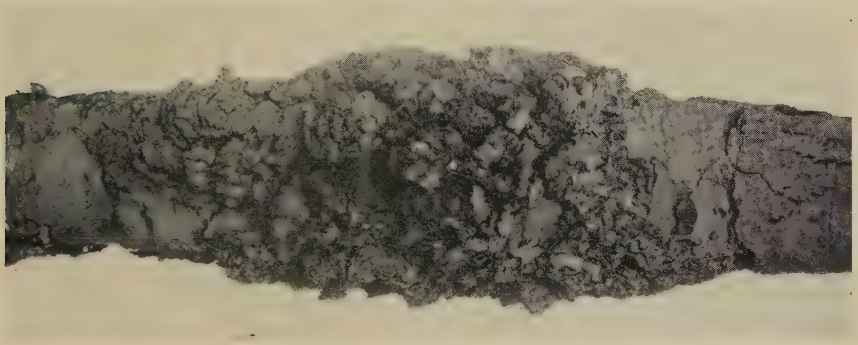


Fig. 2. Typical swollen and fissured canker.

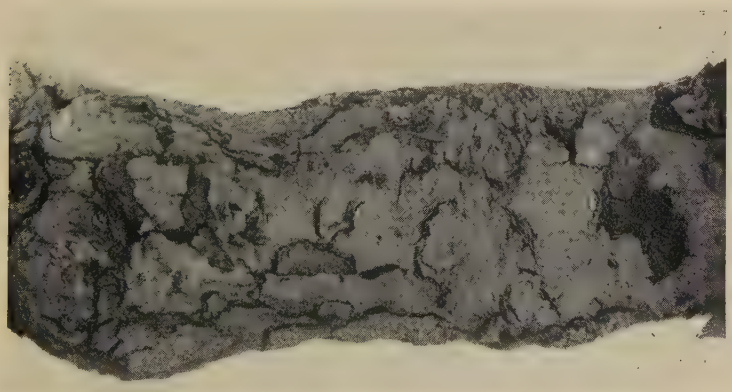


Fig. 3. Part of branch showing scaling bark.

time the diameter of the branch increases in the fissured area, and the characteristic swollen canker is formed (Plate Fig. 2). At first these cankers are clearly localised, but after the branch has been encircled they may extend up and down and cover as much as 1 ft. of the branch. This extension may be preceded by the formation of large, readily detached scales of bark on the branch (Plate Fig. 3). Death does not necessarily follow when the branch has been encircled, and the tree on which the disease was originally recorded has survived for about 15 years though its general condition is now extremely poor. In a number of cases however the peripheral tissues in the fissured area die, and break away and eventually the xylem is exposed; this process continues until the branch is girdled and killed. Since large branches are affected in this way the damage to the tree is severe. Most of the trees under observation are head-worked and the cankers are sometimes near the graft union; there is also a tendency for the cankers to form at the base of dead side shoots.

The anatomy of the canker suggests that the swelling is the result of a local stimulation of the primary cambium which causes an increase in both the phloem and the xylem tissues. The fissuring of the bark follows a progressive degeneration of the outer layers of the peripheral tissues, which are cut off by the formation of successive phellogens. These degenerate tissues shrink and crack giving the characteristic corky fissured surface. Up to the present it has not been possible to determine whether the tissues degenerate as the result of abscission, or whether the abscission layers are formed to cut off degenerating tissue. The life of the branch would appear to depend on the balance between these two processes, and as long as the cambial activity keeps pace with the degeneration of the cortex there appears to be no reason why the branch should die.

General Observations.

In addition to the points raised above there are some observations which may be of interest. The disease seems to occur only on middle-aged or old trees, no symptoms having been seen on trees less than 20 years old, and further, on these trees it was usually the older branches that were affected, no cankers being seen on branches which were less than about 5 years old. This characteristic adds to the potentially destructive action of the disease since one canker will usually affect an appreciable section of the tree.

In three of the orchards examined the soil was derived from middle Lias beds, while on the fourth it consisted of a thin layer of Greensand overlaying Lower Lias Clays. It is unlikely that soil conditions are the cause of the disease since adjacent infected and non-infected orchards are found on similar soils, and within infected orchards there appears to be little pattern in the distribution of affected trees though there is some suggestion that the trouble is spreading from a focus.

Up to the present nothing is known of the etiology of the disease, and the nature of the symptoms offer little ground for speculation since hyperplastic malformations are known to occur in the absence of a pathogen in addition to being symptoms of virus, fungal or bacterial disease. However, the distribution of the disease suggests strongly that it is infectious in nature and may therefore spread and, should it become wide-spread would cause considerable damage. For this reason this preliminary account of the symptoms has been published to bring the existence of the disease to the notice of those concerned with apple production.

A PROGRESS REPORT ON THE EFFECT OF CERTAIN ORGANIC ACIDS ON THE GROWTH OF *NECTRIA GALLIGENA.*

By S. H. CROWDY.

INTRODUCTION.

The object of the present work, which has already been described briefly (1), is to study the effect of stimulating the growth of the host tissues as a possible treatment of the canker disease of the apple (caused by *Nectria galligena* Bres.). While a large number of organic acids, especially phenoxy- and naphthoxy-acids, are known to stimulate development of higher plants (3, 4 and 6) very little is known of their effect on the growth of fungi although it has been reported that 1-naphthylacetic acid reduces the growth of *Ceratostomella ulmi* (Schwag.) Buism. (5) and relatively high concentrations of 2-4-dichlorophenoxyacetic acid stimulate the formation of large and abnormal coremia in cultures of the same fungus (2).

When using substances of this type to treat cankers it was obviously desirable to avoid those which might stimulate the growth of the pathogen and to give preference to those which would depress it : for this reason preliminary studies were made on the growth of *N. galligena* in media containing a selection of the substances. Since the immediate object of these growth studies was to classify a collection of acids in order of toxicity to *N. galligena,* the present note is concerned mainly with the methods employed to measure the effect on the fungus in culture, and their application to a rapid survey of the toxicity of a number of compounds. Preliminary field studies with a selection of these compounds are also described.

Cultural Studies.

The acids used were relatively insoluble in water but dissolved readily in ethyl alcohol or acetone ; the stock solutions used in the tests contained 1% of the acid in one of these solvents. The solvents used ensured that these solutions were sterile and could be added to the medium without risk of introducing contaminations and also without subjecting the acid to a heat treatment.

In the early stages of the work a number of purely qualitative observations were made by placing a small quantity of the solid acid, or its solution, on an established culture of *N. galligena* on malt agar : this gave a rough indication of the toxicity of the acids, and also showed that, even when they were relatively active, their activity appeared to be confined to the actual point of application.

Following these initial tests a quantitative estimate of the activity of the acid was made by measuring the growth of the fungus on 2% malt agar (pH 4·4) containing 100 p.p.m. of the acid, a concentration which was chosen for convenience. The medium was sterilised in 50 cc. lots, and immediately before pouring it was cooled to 45°C and held at that temperature for at least 15 minutes, then the appropriate quantity of the acid solution was added with a sterile pipette and the medium was poured into four 10 cm. petri dishes. Small variations in the quantity of medium in each dish had no effect on the growth rate of the fungus. The dishes were inoculated near their centre with mycelium of the fungus and the increase in diameter of the colony was

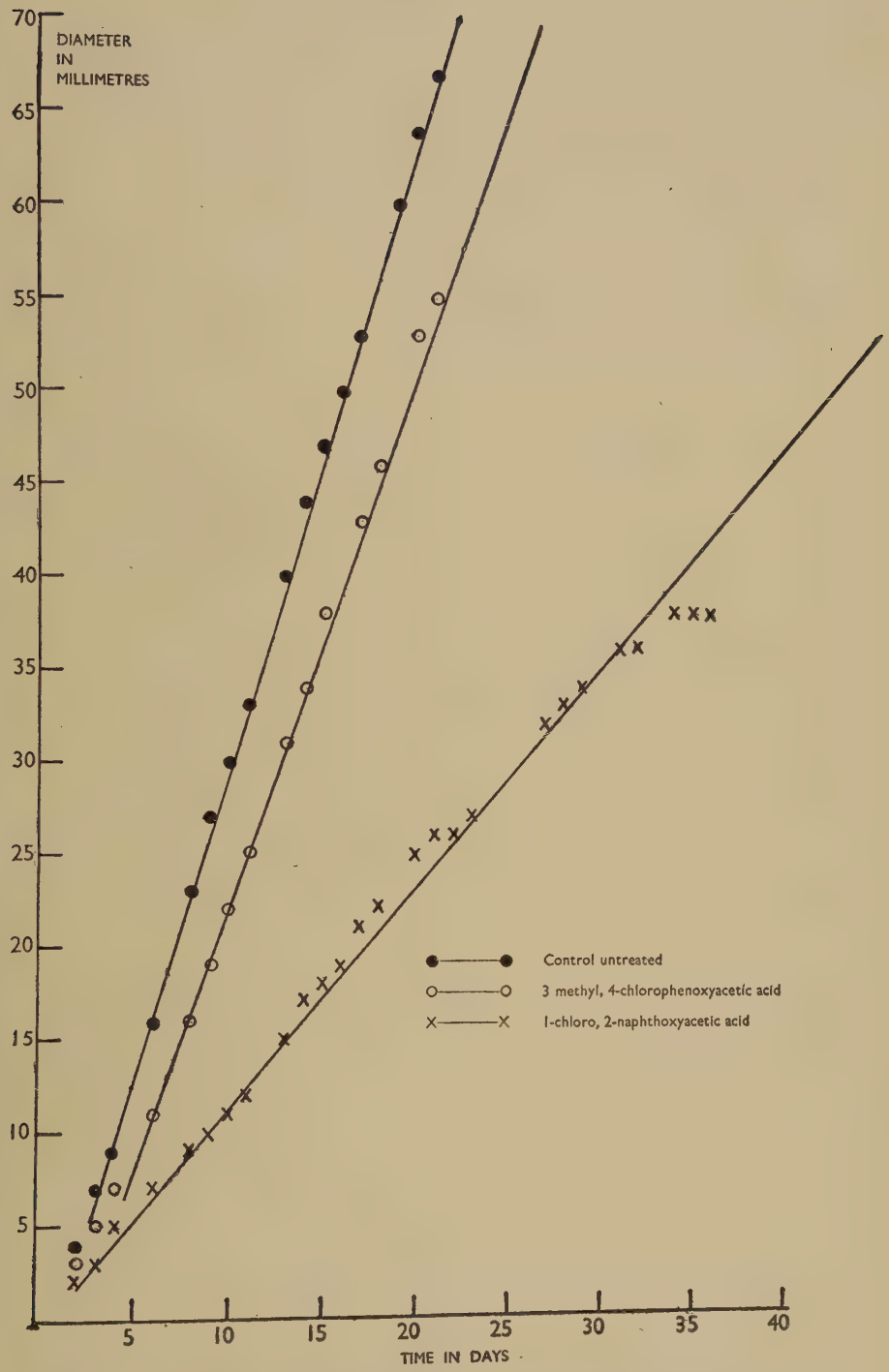


Fig. 1. The effect of the addition of 100 p.p.m. of growth substance to malt agar on the growth of *N. galligena*.

measured at intervals along two diameters which had previously been marked. Controls containing only the solvent were included in each set of readings. In order to avoid errors due to variations in the constitution of the medium the same batch of malt agar was used for all the treatments in one set.

Typical growth curves are shown in Fig. 1 : in most cases the growth rate increased to a maximum during the early stages and then remained constant until the colony approached the edge of the plate or until the agar had had sufficient time to dry out appreciably, when growth slowed down. During the present trials interest was centred on the effect of the acid on the growing fungus, and the slope of the straight part of the growth curve was taken as a measure of the rate of growth. This was calculated as the coefficient of linear regression of diameter on time. Table 1 shows the analysis of variance for the 1-chloro, 2-naphthoxyacetic acid curve (Fig. 1) between the fourth and the thirtieth day :

TABLE I.

Analysis of Variance. Growth Rate of 1-Chloro, 2-Naphthoxyacetic Acid (Regression Coefficient : 1·20 mm. per Day).

Factor	Sums of squares	Degrees of freedom	Variance
Between Arrays	5054	19	
Linear regression	5040	1	
Deviations from regression	14	18	0·78
Within arrays (Error)	103	40	2·57
Total	5157	59	

This analysis is typical of all the trials, and shows how closely a straight line fits the observed data. In order to allow for differences due to the nature and concentrations of the solvents and variations in external conditions, the growth rates were expressed as percentages of the controls.

Experimental Results.

Table II shows the effect of ethyl alcohol and acetone on the growth of *N. galligena*. At the concentrations used during the experiment they tend to increase growth though it is only at a concentration of 1% that the increase can be considered significant : there is no difference between the growth at 1% concentration and that at 2%.

TABLE II.

Effect of Acetone and Alcohol on the Growth of *N. galligena*. Growth Rates in mm. per Day.

Treatment	Concentration		
	0%	1%	2%
Acetone	3·48	3·75*	3·63
Alcohol		3·81*	3·81

* Differ significantly from control ($P = 0·05$).

Table III shows the effect of adding the acids to the medium at a strength of 100 p.p.m. Up to the present too few substances have been tested to show any definite trends, but there are indications that -naphthoxy acids are more toxic than the corresponding -phenoxy acids, and in the -phenoxy series there appears to be a tendency for the toxicity to increase with an increase of chlorine in the ring. The side chain also appears to exert a strong influence on toxicity ; there is little difference between compounds containing acetic and α -propionic acids, but the presence of β -propionic acid appears to be associated with a striking increase in toxicity.

TABLE III.

The Effect of Organic Acids on the Growth of *N. galligena*. Growth Rate % of Control.

4-chloro,2-methylphenoxyacetic acid	105
4-chloro,3-5-diamethylphenoxyacetic acid (2)	100
α(2-chlorophenoxy)propionic acid (1)	98
α(4-chlorophenoxy)-propionic acid (1)	93
2-5-dimethylphenoxyacetic acid (2)	91
2-naphthoxyacetic acid	89
4-chloro,3-methylphenoxyacetic acid (3)	86
indolyl,3-acetic acid	86
4-chlorophenoxyacetic acid (1)	84
2-chlorophenoxyacetic acid (1)	82
γindolyl,3-butyric acid	79
3-methyl,5-ethylphenoxyacetic acid (3)	78
2-4-dichloro,3-5-dimethylphenoxyacetic acid (3)	77
2-4-dichlorophenoxyacetic acid	73
bis-(2-naphthoxy)-acetic acid (2)	65
α(2-naphthoxy)-propionic acid (1)	63
dichloro,3-methyl,5-ethylphenoxyacetic acid (3)	55
α(2-4-dichlorophenoxy)-propionic acid (1)	51
1-naphthylacetic acid	47
α(2-naphthoxy)-*n*-valeric acid (1)	47
2-4-dichloro,1-naphthoxyacetic acid (2)	45
2-4-6-trichlorophenoxyacetic acid (2)	40
α(1-chloro,2-naphthoxy)-propionic acid (1)	38
1-chloro,2-naphthoxyacetic acid (2)	36
β(2-naphthoxy) propionic acid (1)	25
β(2-4-dichlorphenoxy)-propionic acid (1)	5
β(1-chloro,2-naphthoxy)-propionic acid (1)	0

(1) Supplied by Miss R. Walker of Wye College.
(2) Supplied by Pal Chemicals Ltd.
(3) Supplied by Dickinson and Sons Ltd.

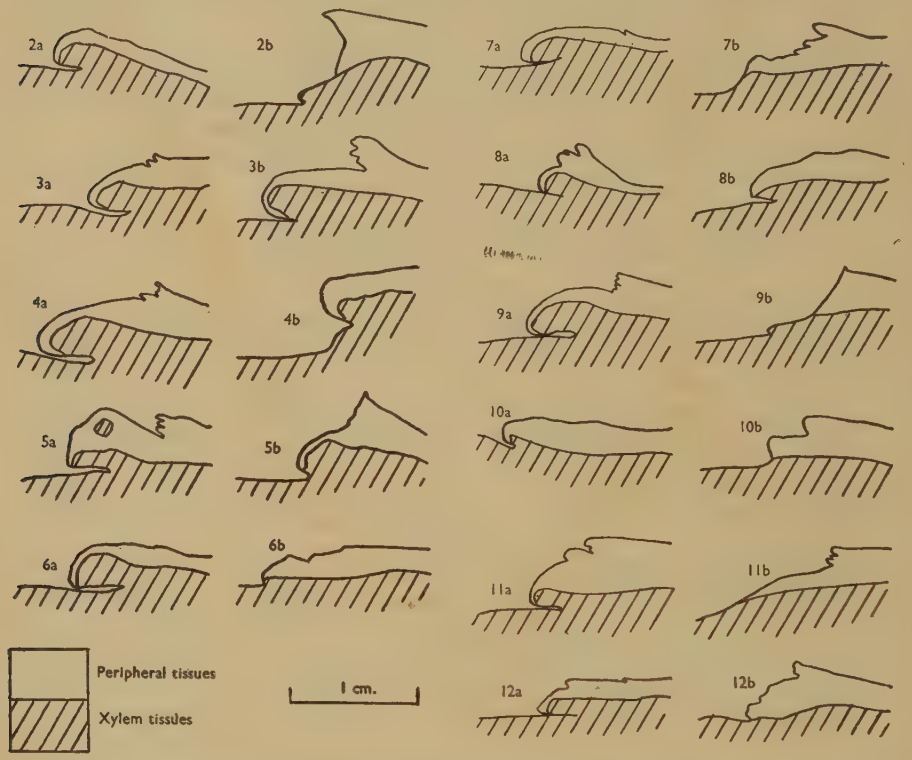
Field Trials.

Preliminary field trials were also carried out: growth substances at a concentration of 1% in lanoline were applied to cankers on Worcester Pearmain in April and the branches were cut for examination in the following October. There were two series of tests ; in the first the cankers were cleaned prior to treatment by cutting out the necrotic tissue and in the second they were treated without cleaning.

In addition to the growth substances two fungicides were included in these tests, Cryptonol[1] and Phygon[2], of which the active principles are respectively 8-hydroxyquinoline sulphate, and 2-3-dichloro,1-4-naphthoquinone. The general effect of these treatments was assessed by comparing the callus formation shown in median longitudinal sections of the treated cankers.

1. Supplied by British Quinolin Ltd.
2. Supplied by United States Rubber Co. Ltd.

Text figures 2-12 show diagramatically the callus formation at the base of these cankers, series *a* refers to cleaned cankers and series *b* to uncleaned cankers. When interpreting these diagrams two points have to be borne in mind : in the first place the development of the xylem tissues gives the best guide to the extent of healing since it is easier to estimate the amount of growth which has taken place since treatment, especially with the cleaned cankers when the dead tissues was cut away at the time of treatment. There



Figs. 2-12 : Longitudinal sections of callus at the base of Cankers treated with lanoline pastes : Series *a* cleaned, series *b* not cleaned. *2*, controls : *3*, γ-indolyl 3,butyric acid : *4*, bis(2-naphthoxy)acetic acid : *5*, 4-chloro,3-5-dimethylphenoxyacetic acid : *6*, 2-4-dichloro,1-naphthoxyacetic acid : *7*, Cryptonol 1% : *8*, Cryptonol 10% : *9*, Phygon 1% : *10*, 2-4-6-trichlorophenoxyacetic acid : *11*, dichloro,3-methyl,5-ethylphenoxy-acetic acid : *12*, 1-chloro,2-naphthoxyacetic acid.

is no clear division between the new and the old tissues outside the xylem. The second point is that all reference to the pathogen has been omitted from the diagrams ; this is of particular importance when considering the uncleaned cankers in which the pathogen is continually spreading and the boundaries represent only a temporary state of affairs. In interpreting these uncleaned cankers however, it is possible to judge by the shape of the wound whether the treatment has been effective since smooth contours (figs. 2b, 7b, 9b, 11b) suggest a steady spread of the fungus and are in contrast to the sudden break in the form of the canker where healing appears to be taking place (figs. 3b, 4b, 5b, 8b). In addition to differences in the quantities of xylem formed after different treatments there were differences in quality and it was possible

to estimate the maturity of the xylem by the extent to which the larger tracheid elements had been differentiated in the callus tissue ; these were quite frequent in some treatments and absent in others. The fact that in interpreting these results attention has been focused on the xylem in the callus tissue should not be allowed to obscure the importance of the peripheral tissues particularly in the uncleaned cankers ; it appears to be the presence of strong wound cambia in these tissues which checks the spread of the pathogen, and allows the development of the underlying xylem. These protective peripheral tissues are shown in figs. 3b, 4b, and 5b.

It will be seen from figs. 3, 4 and 5 that cankers treated with γ -indolyl 3-butyric acid, bis-(2-naphthoxy) acetic acid, and 4-chloro,3-5-dimethylphenoxyacetic acid all show improvement over the controls both in the cleaned and in the uncleaned cankers ; of these only the second showed a marked improvement in the quality of the xylem ; in the other two the extent of differentiation was about the same as in the controls. In contrast to these the quality in the wound xylem was markedly inferior in the cankers treated with 2-4-dichloro,1-naphthoxyacetic acid, 2-4-6-trichlorophenoxyacetic acid and dichloro,3-methyl,5-ethylphenoxyacetic acid (Figs. 6, 10 and 11).

It would appear that, within the limits of toxicity of the plant growth substances used, healing depends more on the stimulation of the callus than on the suppression of the pathogen, though the 10% Cryptonol treatment suggests that suppression of the pathogen can produce an essentially similar effect, even though the compound does not appear to stimulate callus formation (Fig. 8b).

ACKNOWLEDGMENTS.

The author's thanks are due to Dr. L. C. Luckwill and Mr. R. W. Marsh for their advice during the work and to Mr. A. Stringer for advice on the analysis of the results.

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EFFECT OF ORGANIC SPRAY RESIDUES ON CANNED BLACKCURRANTS. II.*

By W. B. ADAM, W. M. DOWSON and R. W. MARSH.

Experiments conducted at Long Ashton and Campden in 1944 and 1945, and described elsewhere (1, 2), have shown that blackcurrant leaf-spot—a disease caused by the fungus *Pseudopeziza ribis*—can be adequately controlled by spraying the bushes with preparations containing ferric dimethyldithio-

* This paper appears also in the 1947 *Campden Report*, from which it is reproduced by permission of the Director of the Campden Research Station.

carbamate two to three weeks before picking. A test made in 1945 to determine the efficacy of a spray containing tetramethylthiuram disulphide (TMTDS) resulted in less defoliation of the sprayed than of the unsprayed bushes, but the difference recorded was not statistically significant and the evidence in favour of control of the disease by this material was therefore considered inadequate. Currants treated with ferric dimethyldithiocarbamate in 1945 carried an amount of spray residue (about 45 p.p.m.) which was independent of the time elapsing since the application of the spray or the subsequent conditions of weathering. The residue decomposed almost completely when the currants were boiled and pulped before canning, but when fruits were canned whole in syrup the final content of ferric dimethyldithiocarbamate in the canned product was about 15 p.p.m. The application of this spray had no appreciable effect on the formation of ascorbic acid during growth of the currants, or its retention during canning and storage. The presence of the undecomposed spray residue on the canned fruit did, however, result in more rapid development of hydrogen swells and the production of a strong objectionable flavour in the canned whole currants. Both the two thiocarbamate sprays were considered unsatisfactory if the currants were to be canned as dessert fruit in syrup, but in no way objectionable if the fruit was to be reduced to a pulp by boiling for ten or fifteen minutes before canning.

The spraying trials described in the present paper were made at Long Ashton in 1946 and 1947 by one of the authors (R.W.M.) and the canning trials were carried out at Campden the day after picking. The two substances previously tested were included in these trials, together with two other thiocarbamate compounds and seven compounds which did not contain sulphur as part of an organic group in the molecule. The substances tested were mainly proprietary articles of known composition, and the objects of the experiments was to note the effects of the sprays in controlling defoliation due to *Pseudopeziza* attack and the tendency of the spray residues to act as accelerators of corrosion or to produce foreign flavours in the canned product.

SPRAYING TRIALS.

By R. W. MARSH.

Materials.

The materials employed in 1946 were :—

Ferric dimethyldithiocarbamate (*Fermate*). The pure material, obtained from Messrs. Robinson Brothers, was milled with sulphite lye in the proportion of 2 lb. dithiocarbamate, 0·2 gall. sulphite lye syrup, 1·8 gall. water. The dispersible paste thus formed was diluted for spraying to give a concentration of 2 lb. dithiocarbamate/100 gall.

Zinc dimethyldithiocarbamate (*Zincate*). This was supplied by Messrs. I.C.I., Ltd., as a dispersible powder containing 80 per cent of the pure compound. It was used at 2½ lb./100 gall. (= 0·2 per cent of the pure material).

Tetramethylthiuram disulphide (*TMTDS*). This material was also obtained from Messrs. I.C.I., Ltd., as a dispersible powder containing 46 per cent of the disulphide. It was used at 4 lb./100 gall. (= 0·18 per cent of the pure compound).

Tetrachlorbenzoquinone (*Spergon*). Commercial Spergon (98 per cent pure) from the U.S. Rubber Co., was compounded with Estol H to give a spray containing 2 lb. tetrachlorbenzoquinone and 2½ pt. Estol H per 100 gall. water.

Tetrachlornitrobenzene (*Folosan*). This was used as 2 lb. Folosan DB 905 /100 gall. Folosan DB 905, supplied by Messrs. Bayer Products, is stated to contain 5 per cent of tetrachlornitrobenzene, giving a concentration in the spray fluid of 0·01 per cent.

Salicylanilide (*Shirlan AG*). This was employed as Shirlan AG, containing 25 per cent salicylanilide, compounded with Agral 2. The spray used was 2 lb. Shirlan AG/100 gall. (= 0·05 per cent salicylanilide).

Phenyl mercury chloride (*Venturicide*). The concentrate used was a Venturicide preparation supplied by Messrs. Lunevale Products, and containing 2½ per cent of the active ingredient. This was used at 1 lb./100 gall., giving a spray containing 0·0025 per cent phenyl mercury chloride.

For the 1947 trials, zinc dimethyldithiocarbamate (80 per cent pure) was used at 1 lb./100 gall. and tetramethylthiuram disulphide (46 per cent pure) at 2 lb. per 100 gall. The other materials included in the trials were :—

Disodium ethylene bis-dithiocarbamate (*Dithane*). The concentrate used was a liquid preparation, Dithane D14, supplied by Messrs. Chas. Lennig & Co. and stated to contain 25 per cent of the active ingredient. In compounding the spray, zinc sulphate and hydrated lime were also used, in the proportions : D14. ½ gall ; zinc sulphate, 1 lb ; hydrated lime, ½ lb ; water 100 gall. The final concentration of the bis-dithiocarbamate was therefore 0·125 per cent.

Heptadecyl glyoxalidine. The concentrate employed was the commercially pure material (Glyoxalidine 341) supplied by the Carbon and Carbide Chemicals Corporation. This was used at 1 lb./100 gall.

Dichlornaphthaquinone (*Phygon*). This material was obtained as Phygon (98 per cent 2 : 3-dichloro-1 : 4-naphthaquinone), manufactured by the U.S. Rubber Co. It was used at 1 lb./100 gall. with 3½ pt. sulphite lye syrup as a dispersing agent.

Hydroxyquinoline sulphate. Material of 8-hydroxyquinoline sulphate monohydrate (neutral) was provided by British Quinoline Ltd. 1 lb. of the concentrate was mixed with 4 oz. hydrated lime to make 100 gall. of spray.

EXPERIMENTAL.

The plot of 224 bushes of Baldwin blackcurrants previously described (1) was again used for both the 1946 and the 1947 trials.

1946 Trials. The plot was divided into five blocks within each of which the seven treatments (see above) and the control were randomized as 4-bush units. Spraying was carried out in dry, warm weather during the period 2nd—11th July, at the rate of approximately 1 gallon per bush, applied with a hand-operated bucket pump. Picking was done on 15th July, and a 2 lb. sample was taken from each treatment unit in each block. The fruit was kept overnight at 37° F. and taken the next day to Campden.

The rainfall figures for August (7·41 in.) and September (4·46 in.) were exceptionally high, but the wet weather did not appear to hasten the spread of *Pseudopeziza* infection. The attack developed at approximately the same

rate as in 1945, and the final estimates of foliage retention were made on 25th September, 1946 (See Table I).

TABLE I.

MEAN PERCENTAGE FOLIAGE RETENTION, 1946.

Code	Spray Treatment	Foliage Retention
		per cent.
B	Tetramethylthiuram disulphide (TMTDS) ..	56·4
H	Zinc dimethyldithiocarbamate (Zincate)	53·0
F	Ferric dimethyldithiocarbamate (Fermate) ..	45·5
A	Phenyl mercury chloride (Venturicide)	37·5
E	Tetrachlorbenzoquinone (Spergon)	37·5
C	Tetrachlornitrobenzene (Folosan DB 905) ..	36·0
D	Salicylanilide (Shirlan AG)	32·5
K	Control	29·0

ANALYSIS OF VARIANCE.

	Sum of Squares	Degrees of Freedom	Variance
Total	9628·45	39	247·0
Treatment	3335·60	7	476·5
Blocks	1535·84	4	384·0
Error	4757·01	28	169·8

In 1946, the significant difference between treatment means for $P = 0{\cdot}05$ was 16·7, *i.e.* Treatment B > E, A, C, D, K : Treatment H > C, D, K : Treatment F > K ; but treatments E, A, C, D were not significantly better than K (control).

1947 Trials. The six treatments and the control were randomized in four blocks, but, as only small quantities of Dithane, glyoxalidine and Phygon were available, 2-bush replicates had to be used for these treatments instead of the standard 4-bush units.

The attack by *Pseudopeziza* started unusually early in 1947. By the third week of June, the foliage around the fruit trusses was already heavily infected, so the spray applications were given on 24-26th June, except for the Dithane spray which was delayed until 7th July by non-arrival of the material. The rate and method of spraying were as in 1946, and the applications were made in dry, sunny weather. Between 26th June and 17th July, when picking was carried out, the rainfall was 2·96 in. The samples were kept as before in cold storage until taken to Campden on 18th July.

In the latter part of July and throughout August the weather was hot and

almost rainless. In these conditions, defoliation proceeded much more rapidly than in previous years. By 6th August, the worst-affected bushes were nine-tenths defoliated so it was decided to make the final assessment of *Pseudopeziza* attack on that date. The results are assembled in Table II.

TABLE II.

MEAN PERCENTAGE FOLIAGE RETENTION, 1947.

Code	Spray Treatment	Foliage Retention
		per cent
F	Disodium ethylene bis-dithiocarbamate (Dithane) ..	65·0
A	Heptadecyl glyoxalidine	62·5
C	Dichlornaphthaquinone (Phygon)	61·2
E	Zinc dimethyldithiocarbamate	54·4
D	Tetramethylthiuram disulphide	48·1
K	Control	25·6
B	Hydroxyquinoline	20·6

ANALYSIS OF VARIANCE.

	Sum of Squares	Degrees of Freedom	Variance
Total	9373·22	27	347·15
Treatment	7866·80	6	1311·13
Blocks	567·84	3	189·28
Error	938·58	18	52·14

In 1947, the significant difference between treatment means for $P = 0{\cdot}05$ was 10·6, *i.e.* treatment F > E, D, B, K : treatments A and C > D, B, K ; treatments E and D > B, K. Treatment B was obviously no better than the control.

CANNING TRIALS.

By W. B. ADAM and W. M. DOWSON.

Tests made in 1946.

Canning Trials. The currants were received on 16th July and immediately filled unstrigged into E1 lacquered cans, at 227 g. (8 oz.) to each can. They were held overnight under cool conditions and canned next morning, the syrup used being 30 degrees Brix and added at a temperature of 180°F. The headspace was adjusted by means of a displacement topper and the cans

clinched, exhausted 5 minutes at 190°F., cooked 12 minutes at 212°F. and cooled. Six cans of each lot were held at normal room temperatures for various tests in the laboratories and the rest were stored at 95°F. for comparison of the rates of formation of hydrogen swells. By conducting the tests on whole currants in syrup, rather than on fruit which had been boiled and pulped, the maximum effect of the spray residues was obtained.

Analytical Methods. The degree of contamination of the raw currants was not determined, but two lots of canned currants—those sprayed with Zincate and TMTDS—were analysed for the particular spray residue. The method used for determining zinc dimethyldithiocarbamate was similar to that suggested by Dickinson (3) for the corresponding ferric compound and consisted briefly of decomposing in an acid medium with distillation of the resultant carbon disulphide into diethylamine and copper acetate. The brown copper salt of diethyldithiocarbamate was then separated and the intensity of the coloured solution determined with a Spekker photoelectric absorptiometer. Analyses for zinc were also made on the samples sprayed with Zincate.

It was found that the method used for estimating ferric dimethyldithiocarbamate gave erratic results when applied to the determination of the closely allied substance TMTDS, and consequently one of the authors (W.M.D.) made a study of the conditions favouring the decomposition of this compound and its determination in minute quantities. In preliminary tests, using pure TMTDS without any fruit present, a recovery of only 15 per cent was increased to 90 per cent by substituting 2*N* sulphuric acid for citric acid in the distillation flask, it being shown in addition that no loss of carbon disulphide or decomposition of copper diethyldithiocarbamate occurred during distillation. Although TMTDS thus exhibited some resistance to decomposition except under highly acid conditions the addition of currants to the contents of the distillation flask produced a very marked reduction in stability and resulted in a rise in yield to about 105 per cent of theoretical, even if no acid had been added. Rapid decomposition of TMTDS, with full recovery was obtained when 0·2 mg. of ascorbic acid was substituted for 10 g. of blackcurrants. The breakdown of TMTDS thus seems to be catalysed by traces of ascorbic acid.

In the method finally adopted for determining traces of TMTDS the apparatus described by Dickinson (3) was used : 260 ml. of water and 5 to 20 ml. 3*N* sulphuric acid were boiled in the distillation flask and cooled with nitrogen passing, after which 5 to 30 g. of the sample were introduced into the flask followed by 5 ml. of chloroform and 1 ml. of 1 per cent ascorbic acid ; 2 ml. of the copper reagent were added to the receiving separator. (Where the test was on blackcurrant pulp the dilute sulphuric acid and ascorbic acid were omitted). Heat was then applied, the flow of nitrogen stopped, and, as soon as the chloroform had distilled over, the separator was raised till the end of the condenser was just below the aqueous layer. Gentle distillation was continued for five minutes, after which the separator was lowered and two lots of 3 ml. of chloroform added to the flask and distilled over. The colorimetric estimation of the copper diethyldithiocarbamate was conducted as described by Dickinson, except that a further 3 ml. of copper reagent, 2·5 ml. of 0·880 ammonium hydroxide and 1 ml. of 25 per cent ammonium chloride were added and the separator shaken for two minutes.

Analytical Results. The amount of ferric dimethyldithiocarbamate present in the canned currants which had been sprayed with Fermate was only 0·6 p.p.m. (in contrast to 15 p.p.m. on the samples treated with this spray in 1945). The samples sprayed with Zincate retained the equivalent of 1·3 p.p.m.

of the spray residue, but the zinc content (4·1 p.p.m. in the unsprayed controls and 7·0 p.p.m. in the test samples) suggested an initial concentration of about 14 p.p.m. of zinc dimethyldithiocarbamate on the raw currants after spraying. The organic portion of the compound must therefore have been largely decomposed by weathering or during the time the cans were being exhausted. The lots sprayed with TMTDS retained about 5 to 6 p.p.m. of the spray residue after canning.

Effect on Corrosion of Containers. In a previous paper (2) it was shown that ferric dimethyldithiocarbamate, which can act as an inhibitor of the corrosion of mild steel, increases the rate of formation of hydrogen in cans owing to the production of a film over exposed tin surfaces. The formation of this film prevents tin from going into solution and acting as an inhibitor of corrosion of the steel base. The relative rates of formation of hydrogen in the cans containing currants treated with the various sprays in the 1946 trials are shown in Table III.

TABLE III.

RATE OF FORMATION OF HYDROGEN SWELLS. 1946 TRIALS. CANS STORED AT 95°F.

Treatment	Time to reach losses shown		Mean Life
	25 per cent	50 per cent	
	weeks	weeks	weeks
Phenyl mercury chloride (Venturicide)	24	26	27·4
Tetrachlornitrobenzene (Folosan)	24	26	26·7
Salicylanilide (Shirlan AG)	24	30	29·2
Tetrachlorbenzoquinone (Spergon)	22	28	27·8
Ferric dimethyldithiocarbamate (Fermate) ..	14	15	18·3
Zinc dimethyldithiocarbamate (Zincate)	14	16	16·7
Tetramethylthiuram disulphide (TMTDS) ..	18	18	18·6
Control	23	25	25·9

It will be seen that the canned samples containing residues of thiocarbamate sprays (Fermate, Zincate and TMTDS) all became hydrogen swells much more rapidly than the remainder, none of which showed any indication of the presence of an accelerator of corrosion. The marked effect of Fermate in the 1946 trials is of particular interest in view of the much lower concentration of spray residue in the cans compared with that recorded in the samples canned in 1945.

Flavour of Canned Samples. There was no detectable foreign flavour in any of the canned samples.

Tests made in 1947.

Canning Trials. The samples were received on 18th July and were canned next day. The canning processes were similar to those used in the 1946 trials.

Analytical Methods. The currants were analysed quantitatively for spray residues from two of the treatments only—Zincate and TMTDS—and the methods were the same as those used in the 1946 trials. No attempt was made

to determine the concentration of Dithane (disodium ethylene bis-dithiocarbamate) on the raw or canned currants, as an analytical method was not available at the time.

Analytical Results. Analyses of the raw currants treated with Zincate showed erratic results due to large sampling errors, but the canned samples contained the equivalent of only 0·9 p.p.m. of zinc dimethyldithiocarbamate estimated on the organic part of the compound. A determination of zinc residues in the canned currants (1·5 p.p.m. in the controls and 4·0 p.p.m. in the treated samples) suggested an initial concentration of about 12 p.p.m. of Zincate on the currants after spraying. Considerable decomposition of the compound had thus taken place between the spraying of the currants and the seaming of the cans. The residue of TMTDS in the samples treated with this spray was 0·5 p.p.m. in the cans examined, which was a much lower concentration than that found in the corresponding samples in the 1946 trials.

Effect of Corrosion on the Containers. The relative rates of formation of hydrogen in the cans containing currants treated with the various sprays in the 1947 trials are shown in Table IV.

TABLE IV.

RATE OF FORMATION OF HYDROGEN SWELLS. 1947 TRIALS. CANS STORED AT 95°F.

Treatment	Time to reach losses shown		Mean Life
	25 per cent	50 per cent	
	weeks	weeks	weeks
Dichlornaphthaquinone (Phygon)	23	31	—
Heptadecyl glyoxalidine	39	—	—
Hydroxyquinoline sulphate	35	—	—
Zinc dimethyldithiocarbamate (Zincate)	19	20	21·5
Disodium ethylene bis-dithiocarbamate (Dithane) ..	15	18	18·9
Tetramethylthiuram disulphide (TMTDS) ..	18	23	26·7
Control	37	42	—

The three thiocarbamate-type sprays—Zincate, Dithane and TMTDS—produced a more rapid formation of hydrogen swells than any of the others and thus confirmed previous findings that the organic sulphur group common to these compounds acted as an accelerator of corrosion in the canned fruit.

Flavour of Canned Samples. A slight, but distinct, foreign flavour was detected in the sample treated with Dithane, and a very faint foreign flavour was noted in the Zincate sample by two experienced tasters out of five. None of the other treatments had any appreciable effect on the flavour of the canned currants.

SUMMARY AND CONCLUSIONS.

The results of the spraying and canning trials conducted in 1946 and 1947 may be summarized as follows :—

1. Only three of the seven spray treatments given in 1946 resulted in a significant reduction in defoliation of the currant bushes, and all three were sulphur-containing sprays of the thiocarbamate type. The sprays which

controlled the attack by *Pseudopezizia* were tetramethylthiuram disulphide, zinc dimethyldithiocarbamate and ferric dimethyldithiocarbamate. It is of interest to note that the first of these was tested in the 1945 trials and its efficacy not proved on that occasion.

2. In tests made on the canned currants the concentration of the organic portion of the spray residue in the samples treated with ferric and zinc dimethyldithiocarbamates was of the order of one part per million. The concentration of spray residue on the samples treated with tetramethylthiuram disulphide was about five parts per million. These minute traces of sulphur-containing spray residues in the cans were sufficient to produce considerable acceleration in the rate of production of hydrogen swells. None of the other sprays affected the rate of internal corrosion of the cans. There was no detectable foreign flavour in the canned currants from any of the spray treatments.

3. In the 1947 trials five of the six spray treatments resulted in a significant reduction in defoliation of the bushes. The effective sprays were disodium ethylene bis-dithiocarbamate, heptadecyl glyoxalidine, dichlornaphthaquinone, zinc dimethyldithiocarbamate and tetramethylthiuram disulphide. The spray treatment which did not produce results significantly different from the unsprayed control was 8-hydroxyquinoline sulphate.

4. The concentration of organic spray residues from the 1947 samples treated with zinc dimethyldithiocarbamate and tetramethylthiuram disulphide was of the order of one part per million in the canned currants. It was again noted that the use of sprays of the thiocarbamate type—disodium ethylene bis-dithiocarbamate, zinc dimethyldithiocarbamate and tetramethylthiuram disulphide—resulted in an increase in the rate of formation of hydrogen swells. The first of these produced a distinct foreign flavour, and the second a very faint foreign flavour, in the canned samples at the concentrations present.

The conclusions to be drawn from the 1946 and 1947 trials are that, whereas the four sprays of the thiocarbamate type tested are effective in controlling the attack of *Pseudopezezia*, their residues stimulate the rate of production of hydrogen in the cans, even at very low concentrations, and may also adversely affect the flavour. This only applies to cases where the currants are canned whole as dessert fruit, and not as preheated pulp. Heptadecyl glyoxalidine proved to be efficacious and yet had no undesirable characteristic as regards stimulation of corrosion or production of foreign flavour. This spray merits further investigation.

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THE CHEMISTRY OF CIDER.

I. SOME ASPECTS OF THE CHEMICAL COMPOSITION OF YARLINGTON MILL AND MEDAILLE D'OR CIDERS

By S. W. CHALLINOR and L. R. BURROUGHS.

In previous years numerous ciders have been made from juices of apples of single varieties and these " Cider-Making Trials " have been described in former Annual reports. Although analyses of certain constituents of the juices (e.g. " tannins ", total acids, total nitrogen) have been made, little time has been available for analysis of the resulting ciders. It is realised that the final test of a cider must be its value as a beverage—its taste, aroma, general effect upon the palate, appearance, etc. These qualities are determined by the constituents present and a knowledge of the chemical composition of cider is therefore of fundamental importance.

In the present paper preliminary data relating to two groups of ciders prepared from apples of the varieties (a) Yarlington Mill (b) Medaille d'Or are presented. Relevant analytical data for the juices from which the ciders were made are also included when available ; these do not normally include analyses at time of filtration. The ciders in each group were from apples of the same variety grown on bush trees at widely different sites. Both groups of ciders belong to the bittersweet class and were of high vintage quality. Ciders prepared from apples of the variety Yarlington Mill are of particular interest since this is one of the small group of cider apple varieties now recommended for planting. Medaille d'Or ciders are of special interest as they contain unusually large amounts of tannins.

CIDER MAKING PROCEDURE.

All fruit was stored in open trays in the cider-house and was in good condition when processed. Apples of the Yarlington Mill variety were milled and pressed (Table I) during November, 1946, whereas the Medaille d'Or fruit, a very late variety, was processed partly in November, 1946 (juices 63 and 64) and partly in January, 1947 (juices 96, 97 and 98). The fermentation of six of the juices was completed within a period of seven weeks ; the fermentation of juice 66 was slow (eleven weeks) and was completed in January. The early stages of fermentation of the three Medaille d'Or juices (96, 97 and 98) and the later stages of fermentation of juices 63 and 67 were in progress during the abnormally cold weather which started in January 1947, and continued during February and part of March ; these fermentations were slow and continued until late March-April and one, 98, was still in fermentation during May.

The fermentations were carried out on an experimental scale in glass jars fitted with fermentation locks (*1*). The size of the fermenting vessel was determined by the amount of juice available ; most juices were fermented in $2\frac{1}{4}$-gallon jars, Nos. 53, 67, 97 and 98 in 1-gallon jars and No. 64 in a Winchester ($\frac{1}{2}$-gallon). Comparison of the organoleptic characters of individual ciders within a group, or of ciders in different groups may best be made when their specific gravities are approximately equal. Accordingly, fermentation of the juices irrespective of their original specific gravities, was allowed to proceed at ordinary temperatures in the cider-house until their specific gravities had fallen to a given value—about 1025. At this stage fermentation was checked

by filtration through a Meta-filter. Owing to variation in the original gravities of the juices, the decreases in specific gravity varied widely (Table I) and were greater in the Medaille d'Or than in the Yarlington Mill juices. One of the Medaille d'Or juices (98) behaved differently from all the other juices—it fermented very slowly and the S.G. fell from the abnormally high value of 1092 to 1039 and remained substantially constant during several weeks; this cider was filtered at S.G. 1039. The fermentation of juice 64 was also of special interest—it showed the relatively infrequent phenomenon of "dropping-bright" (*2*)—furthermore, the phenomenon was observed on the second day after pressing. After filtration the ciders were bottled in Champagne pints which had been sterilised with 2% SO_2 solution on the Seitz-wheel and corked (the corks had also been sterilised with SO_2). The bottled ciders were then stored in the cellar for periods of time varying from 10–15 months, depending upon the time of bottling; these storage times were rather longer than usual. Fermentation continued slowly in the bottles and further decreases in specific gravity occurred averaging 8° and 5° for the Yarlington Mill and Medaille d'Or ciders respectively. During this storage the carbon dioxide which is produced "conditions" the cider and other changes associated with maturing take place.

CHEMICAL CONSTITUENTS OF THE JUICES AND CIDERS.

In subsequent pages of this paper the estimation of certain constituents of the ciders and juices is described. Before analysis all ciders and juices were filtered under slightly reduced pressure through kieselguhr.

Nitrogen Contents of the Juices in Relation to Fermentation.

All nitrogen estimations were made by the Kjeldahl method using the Markham apparatus (*3*) and the results are summarized in Table I. Juices varied greatly in total nitrogen which ranged from 3·34–15·6 mg. per 100 ml. As fermentation had been checked at S.G. 1025, the extent of the fermentation in the different juices was largely determined by their original gravities. Considerable fermentation occurred in some of the juices, the decreases in S.G. varying from 28–63 degrees. It is of interest that the nitrogen present in each of the juices was sufficient for these fermentations to occur. For example, in the two juices 67 and 98, the decreases in S.G. were as much as $41\frac{1}{2}$ and 56 degrees respectively, although their nitrogen contents were low (3·34 and 5·0 mg. per 100 ml.); furthermore, their fermentations were subject to abnormally low temperatures. Fermentation of juice 98 however, ceased at S.G. 1039 and appeared to be limited by its relatively low nitrogen content; nitrogen also appeared to be the limiting factor in the fermentations of juices 67 and 66. The significance of these results is discussed later in the paragraph on "available nitrogen."

In this section, rates of fermentation are considered in relation to the total nitrogen of the juices and to the "nitrogen used per 10° decrease in S.G. of primary fermentation." The expression "*nitrogen used*" was obtained by subtracting the amount of nitrogen remaining in the bottled cider from the total nitrogen originally present in the juice; it represents the nitrogen used during *both* the primary alcoholic fermentation and the subsequent fermentation which occurred in the bottle. In these experiments the nitrogen contents of the ciders at the time of filtration were not determined and the decreases in the nitrogen contents which occurred "in bottle" were not, therefore, known. However, "fermentation in bottle" was brought about by the relatively small number of micro-organisms present after filtration and these organisms had

TABLE I.

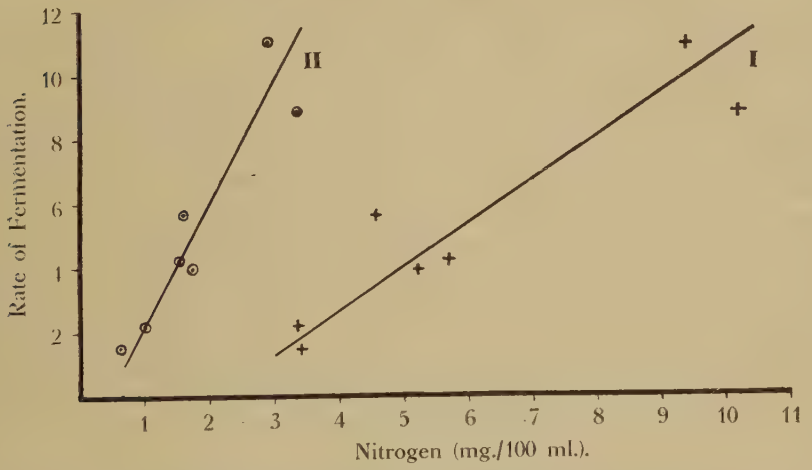
SPECIFIC GRAVITIES, RATES OF FERMENTATION AND NITROGEN.
(Data arranged in decreasing order of rates of fermentation).

VARIETY	No. of Sample	Date of Milling and Pressing	Specific Gravity of Fresh Juice	Date of Filtration	Specific Gravity at time of Filtration	Specific Gravity of Cider in Bottle (1st March 1948)*	Decrease in Specific Gravity (degrees)			Average Rate of Primary Fermentation	Nitrogen (mg/100 ml.)			
							a. During Primary Fermentation	b. During Fermentation in Bottle	a. + b. Total Decrease in S.G.		Total Nitrogen in Juice	Residual Nitrogen in Cider (1st March 1948)	"Nitrogen used" during Total (a + b) Fermentation†	"Nitrogen used" per 10° decrease in S.G. (of primary fermentation)†
YARLINGTON MILL	65	6/11/46	1052	23/11/46	1025	1014·5	27	10·5	37·5	11·1	9·43	1·63	7·80	2·90
	74	22/11/46	1051	12/12/46	1025·5	1012	25·5	13·5	39	8·9	10·24	1·75	8·49	3·35
	68	6/11/46	1047	3/12/46	1025	1019	22	6	28	5·7	4·57	1·07	3·50	1·60
	53	29/10/46	1052	14/1/47	1022·5	1019·5	29·5	3	32·5	4·3	5·71	1·20	4·51	1·55
	73	22/11/46	1046	31/12/46	1024	1015	22	9	31	4·0	5·24	1·34	3·90	1·75
	66	6/11/46	1049	21/1/47	1025	1016·5	24	8·5	32·5	2·2	3·34	0·89	2·45	1·00
	67	6/11/46	1063	26/4/47	1025·5	1021·5	37·5	4	41·5	1·5	3·40	1·08	2·32	0·60
MEDAILLE D'OR	64	5/11/46	1074	25/11/46	1022	1018	52	4	56	18·2	15·58	3·30	12·28	2·35
	97	8/1/47	1085	19/4/47	1026	1022·5	59	3·5	62·5	4·1	8·31	2·78	5·33	0·90
	96	8/1/47	1063	23/3/47	1021	1010	42	11	53	4·0	13·58	3·34	10·24	2·45
	63	5/11/46	1077	22/3/47	1025	1021	52	4	56	3·4	7·89	2·96	4·93	0·95
	98	8/1/47	1092	15/5/47	1039	1036‡	53	3	56	2·9	4·98	2·49	2·49	0·45

* The specific gravities of the ciders in bottle were determined by weighing (Specific Gravity bottle). All other specific gravities were determined by hydrometer.
† The significance of these figures is explained in the text. Example for juice 53 : "Nitrogen used per 10° decrease in S.G." = (57·1 − 1·20) mg. $\frac{}{}$ 29·5 × 10 = 1·55 mg. N.
‡ The reason for this abnormally high specific gravity is given in the text.

a long time (10–15 months) in which to bring about that fermentation. The changes which were produced in the nitrogen contents of the ciders were probably smaller than when a similar amount of fermentation occurred in the course of primary alcoholic fermentation. This was illustrated by the small amounts of the deposits (mainly yeasts) which were present in the bottled ciders even when considerable fermentation had occurred in the bottle. It is reasonable, therefore, to assume that the difference between the nitrogen content of the fresh juice and that of the bottled cider (i.e. the nitrogen used during both the primary alcoholic fermentation and during the fermentation in the bottle) was *approximately* the same as that amount of nitrogen which was used during the primary alcoholic fermentation alone. Furthermore, since the extents of the primary fermentations were much greater than those of the fermentations in the bottle it will be realised that this assumption was justified for most of the ciders. Accordingly, in the next paragraph in which rate of fermentation is compared with the nitrogen used during *primary* fermentation the comparison is, in fact, made between rate of fermentation (primary) and the nitrogen used during the total fermentation. In order to allow for the widely different extents of these primary alcoholic fermentations the "nitrogen used per 10° decrease in S.G." (i.e. per 10° of primary fermentation) was chosen for the comparison, rather than the nitrogen used during the entire course of primary fermentation.

THE RELATIONSHIP BETWEEN NITROGEN AND AVERAGE RATE OF PRIMARY FERMENTATION.



Curve I—Rate of fermentation and total nitrogen content of the juices.

Curve II—Rate of fermentation and "nitrogen used per 10° decrease in S.G. of primary fermentation."

Rates of Fermentation. The average rate of primary alcoholic fermentation was calculated by dividing the number of degrees of specific gravity lost during the fermentation by the number of weeks required to bring about the change (the duration of the fermentation prior to bottling); the results represent the *average rates of primary fermentation at cider-house temperatures.* These temperatures were variable but in spite of this, when the average rates of primary fermentation (Table I) of the Yarlington Mill juices were considered

in relation to nitrogen two interesting correlations were observed: thus the rates were approximately proportional (1) to the total nitrogen of the juices and (2) to the amounts of " nitrogen used per 10° decrease in specific gravity " (primary fermentation). These relationships are illustrated by the analytical data in Table I and by the graph.

When the rates of fermentation of the Medaille d'Or juices were considered in relation to nitrogen similar correlations were found. Too much importance, however, should not be attached to the correlations in this series because the fermentation of three of the juices (96, 97 and 98) had commenced at abnormally low temperatures and their fermentations cannot therefore be regarded as normal. Thus, the fermentations of two of these juices were in fact somewhat abnormal: No. 96, which had the second highest nitrogen of all the Medaille d'Or juices, had a rate of fermentation of 4 only, and No. 98, as previously stated, would not ferment below 1039, although its rate of fermentation was not abnormally low in comparison with other juices of the variety.

The proportions of the total nitrogen of the juices which were " available " to the yeasts are of particular interest. The " nitrogen used " is part only of the " available nitrogen " except for those juices in which fermentation had ceased, or almost ceased, because of lack of nitrogen. When this occurred it was considered reasonable to regard the " nitrogen used " as representing the nitrogen available to the yeasts, since all the juices contained residual sugar and cessation of fermentation could therefore reasonably be attributed to lack of available nitrogen. This condition is satisfied by juices 66 and 67 of the Yarlington Mill series and by the Medaille d'Or juices 96 and 98. Consideration of the latter two juices is omitted because their fermentations had commenced at abnormally low temperatures. For juices 66 and 67 the *ratios* of the " nitrogen used ", i.e. available nitrogen, to the total nitrogen originally present in the juices were 73% and 68%. It is interesting to compare these ratios with the corresponding ratios for those juices which fermented rapidly and in which part only of the available nitrogen was used. These latter ratios were high and were mostly of the order of 80% and in these juices it would appear that a greater proportion of the total nitrogen was available to the yeasts than in the slowly fermenting juices 66 and 67.

In this section the nitrogen of the juices has been considered in relation to primary alcoholic fermentation. Some fermentation also occurred in the bottle and this was variable in amount, the decreases in specific gravity ranging from 3–13½ degrees. The *residual available nitrogen* present in the cider at the time of filtering and bottling is a major factor in determining the extent of fermentation which will occur in the bottled cider (*4*). As already stated the nitrogen contents of the ciders at the time of filtration were not estimated and it is not possible therefore to correlate the extent of fermentation which took place in the bottle with the *nitrogen used* in that fermentation. In the earlier part of this section, reasons have been brought forward to show that the amount of nitrogen used by the relatively few micro-organisms responsible for fermentation in the bottle was small. It can, however be stated that all those ciders which fermented only to a small extent in the bottle (e.g. a decrease in S.G. of 3–4 degrees) had relatively large concentrations of nitrogen even at the end of this fermentation (Table I). It is probable that the residual nitrogen in such ciders was in a form not readily available to the micro-organisms. The number and nature of the yeasts and bacteria present in the cider is obviously also of importance in this connexion. The relative importance of these factors in determining the extent of fermentation which takes place in bottled cider

TABLE II.

ANALYTICAL DATA OF CIDERS (AND JUICES) EXCLUDING ANALYSES OF "VOLATILE CONSTITUENTS OTHER THAN ALCOHOL".

VARIETY	Site	No.	Specific Gravity		Average Rate of Primary Fermentation	Total Decrease in S.G. (degrees)	Alcohols as Ethyl Alcohol (g/100 ml.)	Total Acidity as Malic Acid (g/100 ml.)		Increase in Total Acidity as Malic Acid (g/100 ml.)	pH		"Tannin" (g/100 ml.)		SAMPLING 22/1/48	
			Juice	Cider 1/3/48				Juice	Cider		Juice	Cider	Juice	Cider	Specific Gravity of Cider	Merit
YARLINGTON MILL	Faversham	65	1052	1014·5	11·1	37·5	3·53	0·16	0·35	0·19	3·85	3·45	0·34	0·25	1020	4
	Hereford	74	1051	1012	8·9	39	3·90	0·20	0·405	0·205	4·00	3·60	0·32	0·26	1020	4—
	Much Marcle	68	1047	1019	5·7	28	2·30	0·15	0·265	0·115	4·10	3·85	0·23	0·18	1018	4+
	Newnham Bridge	53	1052	1019·5	4·3	32·5	3·10	0·185	0·35	0·165	3·85	3·70	0·27	0·23	1021	4
	Whimple	73	1046	1015	4·0	31	3·04	0·16	0·355	0·195	4·00	3·65	0·24	0·20	1018	4—
	Compton Greenfield	66	1049	1016·5	2·2	32·5	3·00	0·17	0·32	0·15	4·05	3·80	0·31	0·22	1021	4+
	Poundisford	67	1063	1021·5	1·5	41·5	3·33	0·31	0·40	0·09	3·95	3·95	0·56	0·40	1023	4—
MEDAILLE D'OR	Much Marcle	64	1074	1018	18·2	56	4·90	0·25	0·355	0·105	4·15	3·95	0·36	0·25	1022	5
	Newnham Bridge	97	1085	1022·5	4·1	62·5	5·79	0·195	0·20	0·005	4·45	4·30	0·43	0·39	1024	5+
	Hereford	96	1063	1010	4·0	53	4·59	0·245	0·41	0·165	4·10	3·85	0·51	0·46	1014	4—
	Faversham	63	1077	1021	3·4	56	5·55	0·19	0·425	0·235	4·10	3·70	0·45	0·33	1022	4—
	Poundisford	98	1092	1036‡	2·9	56	4·73	0·24	0·235	—0·005	4·40	4·35	0·46	0·40	1036	5+

‡ The reason for this abnormally high specific gravity is given in the text.

cannot adequately be assessed with the data at present available. It is hoped that it will possible in the future to investigate further this most important and interesting aspect of the work.

Alcohols.

Estimation of the alcohol content of a cider usually involves distillation, determination of the specific gravity of the distillate, and reference to official specific gravity/alcohol tables. These tables, however, refer to aqueous solutions containing ethyl alcohol only and, since the distillates obtained from cider contain volatile substances as well as ethyl alcohol, a more specific method is required. The method adopted here involved treatment of the distillate to remove interfering substances (such as aldehydes, ketones and volatile acids) and the alcohols in this *purified* distillate were then estimated by an oxidation process. Methods of estimation of alcohol in cider will be discussed more fully in a subsequent paper.

Method. The procedure adopted was based on the method of Friedemann and Klaas for estimating alcohol in blood (*5*). Interfering substances in the distillates from ciders were removed by treatment with $HgSO_4$ and $Ca(OH)_2$; the alcohols were then oxidised by alkaline $N/10$ $KMnO_4$ and the excess $KMnO_4$ estimated by an iodometric titration. Results were expressed as ethyl alcohol by weight—g. per 100 ml. cider. It follows from what has been said above concerning the specificity of the method of estimation, that all alcohols present in the ciders will have been estimated as ethyl alcohol. A full description of this method will be given in a subsequent paper.

Results. The amount of alcohol produced in a cider depends upon the quantity of sugar fermented and this is directly related to the decrease which has occurred in the specific gravity of the juice. Since the primary alcoholic fermentation was stopped at approximately S.G. 1025 (except for juice 98) decrease in specific gravity was largely determined by the original gravity of the juices. In addition to this primary alcoholic fermentation there was also a slow fermentation in the bottle and the resulting further decrease in specific gravity varied considerably (3–13½ degrees). The exact relation between degrees of specific gravity lost and the amount of alcohol produced will be discussed in a subsequent paper.

There was a greater decrease in specific gravity in the Medaille d'Or than in the Yarlington Mill ciders, as shown in Table II and the alcohol contents, expressed as g. per 100 ml. cider, ranged from 4·59%–5·79% (av. 5·11%) and from 2·30%–3·90% (av. 3·17%) in the Medaille d'Or and Yarlington Mill ciders respectively. The alcohol contents of the Medaille d'Or ciders are of interest as they are rather high (as expected from the original gravities of the juices) for naturally sweet ciders.

Volatile Constituents other than Alcohol.

These constituents may be divided into :—

1. Volatile neutral substances, which include
   - (a) Esters
   - (b) Aldehydes
2. Volatile acids.

1. *Volatile Neutral Substances.*

(a) *Esters.* The method of estimation was based on that of Ribéreau—

Gayon and Peynaud for estimation of esters in wine (*6*). An aliquot (50 ml.) of the *unpurified* alcohol distillate was made alkaline by the addition of $N/10$ NaOH (20 ml.) and allowed to stand at room temperature in a stoppered flask for $2\frac{1}{2}$ hours. The excess NaOH was then titrated with $N/10$ H_2SO_4 (indicator: cresol-red screened with methylene-blue). A blank titration on 50 ml. of freshly-boiled (and cooled) distilled water was carried out. The total amount of NaOH used effected the hydrolysis of the esters and also neutralised the free acidity of the distillate. This acidity was determined in a separate portion of the distillate and the amount of NaOH required for hydrolysis of the esters was obtained by difference; the esters were calculated as ethyl acetate. According to the authors of the method, recovery of esters is 90–95% and our results were therefore multiplied by the factor 10/9.

TABLE III.

Volatile Constituents other than alcohol.

Variety	No.	Average Rate of Primary Fermentation	Volatile Acidity As Acetic Acid (g./100 ml.)	Esters As Ethyl Acetate (mg./100 ml.)	Aldehydes As Acetaldehyde (mg./100 ml.)
Yarlington Mill	65	11·1	0·02	–	4·3
	74	8·9	0·03	1	5·2
	68	5·7	0·07	2	3·6
	53	4·3	0·10	–	3·6
	73	4·0	0·02	7	4·4
	66	2·2	0·09	7	2·7
	67	1·5	0·16	2	3·1
Medaille D'or	64	18·2	0·01	5	2·9
	97	4·1	0·03	4	4·8
	96	4·0	0·10	11	8·5
	63	3·4	0·02	–	4·4
	98	2·9	0·05	29	6·7

The distillation procedure adopted in these estimations differed slightly from that of the authors which involves addition of water (10 ml.) to wine (100 ml.) and collection of 100 ml. of distillate. Insufficient cider was available for a separate distillation and esters had to be determined on part of the distillate obtained in the course of the alcohol determinations. This distillate (100 ml.) was obtained from cider (100 ml.) to which a greater volume of water (25 ml. instead of 10 ml.) had been added. This minor departure from the recommended procedure may possibly have given a slightly less efficient recovery of esters than that claimed (90–95%) by the authors, although this is not considered likely.

The amounts of esters in some of these ciders were exceedingly small and, as very little NaOH was required for hydrolysis, the error involved in its

measurement was relatively great. This error may possibly be reduced by using a weaker alkali ; a longer time for hydrolysis might then be required.

Results. Most of the ciders contained very small amounts of esters (Table III) ; in three of the ciders the amounts of esters were below the limit of detection of the method employed. Two of the Medaille d'Or ciders (98 and 96) contained relatively large amounts of esters ; these two ciders were from juices which had fermented at abnormally low temperatures ; this, however, applied also to cider 97 and direct correlation between temperature of fermentation and ester content of a cider was not possible.

(b) *Aldehydes.* The method of estimation employed was that described by Ribéreau-Gayon and Peynaud for estimation of aldehydes in wine (*7*). Cider (25 ml.) was neutralised with NaOH and then treated with 25 ml. of borate buffer (25 g. sodium borate and 25 ml. *N*. H_2SO_4 made up to one litre). This acid-buffer effected the liberation of aldehydes from combination with other substances present in the cider, e.g. SO_2 and/or tannins. The buffered cider was distilled through a spiral condenser, and 25 ml. of distillate was collected in a mixture of 25 ml. of phosphate buffer, pH 7 (15 g. $Na_2HPO_4.12H_2O$ and 3·35 g. KH_2PO_4 made up to one litre) and 5 ml. of 2% sodium bisulphite solution. The time taken for distillation (15–20 mins.) was sufficient for the aldehydes in the distillate to combine with the bisulphite at pH 7.

The solution containing the aldehyde-bisulphite complex was then made acid (5 ml. of approx. 3*N*. HCl) to prevent dissociation of the complex during the subsequent titration with *N*/10 iodine which removed the excess of free SO_2. The final end-point was obtained with *N*/50 iodine (starch as indicator)) The solution was then titrated with alkaline borate (3% boric acid in *N*. NaOH. to pH 9, with phenolphthalein as indicator and, under these conditions, the aldehyde-bisulphite complex was readily dissociated. The SO_2 liberated was immediately titrated with *N*/50 iodine to the same end-point as before ; this titration represented the amount of SO_2 combined with the aldehydes present in the original sample of cider. Aldehydes were expressed as acetaldehyde— 1 ml. *N*/50 iodine $\equiv$ 0·44 mg. CH_3CHO.

Results. Aldehyde contents of the ciders varied appreciably (Table III). Ciders 96 and 98 which contained the two greatest amounts of aldehydes also had the two greatest amounts of esters. There did not appear, however, to be any close correlation between content of aldehydes and any other property of the cider.

Volatile Acids.

There are various methods available for estimation of volatile acids in wines, and Charley (*8*) has described methods of estimating these acids in cider. The principle of one of the latter methods is similar to a method described in the A.O.A.C. Methods of Analysis for estimation of volatile acids in wine (*9*), and our procedure is based on this method.

Cider (5 ml.), which had been treated to remove CO_2, was steam-distilled (*10*) from a Markham distillation apparatus in the presence of $MgSO_4.7H_2O$ (3·5 g.) and tannic acid (1 ml. of a 5% solution, added to prevent frothing). The magnesium sulphate was added to facilitate removal of the volatile acids (*11*). Distillation was continued until 50 ml. of the distillate had been collected. This volume of distillate was chosen as a result of experiments in which the acid present in different fractions of distillate, up to a total volume of 80 ml., was estimated ; recovery was shown to be reasonably complete in 50 ml. of

distillate. Carbon dioxide-free air was bubbled through the distillate, cresol-red screened with methylene-blue added as indicator and the volatile acids estimated by titration with *N*/60 NaOH. Results were expressed as g. acetic acid per 100 ml. cider.

Results. Volatile acidity varied widely in each group of ciders (Table III). Those ciders which had fermented rapidly had a low volatile acidity (e.g. 65, 74 and 64) and high volatile acidity was associated with a slow rate of fermentation (67, 66, 53 and 96). When volatile acidity was plotted against rate of fermentation for the Yarlington Mill ciders there appeared to be a correlation :—volatile acidity decreased with increase in the rate of fermentation. This correlation however, was not close—for example the volatile acidity of cider 73 was much lower than expected from its rate of fermentation.

In the Medaille d'Or series, the two ciders 96 and 98 with highest volatile acidities had slow rates of fermentation. Four of the five ciders had volatile acidities which varied appreciably although their rates of fermentation differed only slightly ; for these ciders therefore no real correlation was possible between volatile acidity and rate of fermentation.

Total Acidity.

Total acidity was estimated both in juices and in ciders by the method described by Burroughs (12). Precautions were taken to remove carbon dioxide from all ciders before estimation. Cider or juice (10 mls.) was diluted with 100 ml. of CO_2-free distilled water containing bromo-thymol blue/phenol red as indicator and then titrated with *N*/6·7 NaOH in a stream of CO_2-free air. Results were expressed as percentages of malic acid. (g./100 ml.)

Results. In the Yarlington Mill juices total acidity ranged from 0·15% to 0·31% and in the ciders from 0·27% to 0·41% (Table II). The acidity of these juices was typical for the variety with the exception of 67 which was high in comparison with the others. Each of the ciders had a greater acidity than that of the corresponding juice and the *increase* in acidity was considerable, ranging from 76% to 120% except for 67 which had an increase of 30%. *Increase in total acidity* was plotted against rate of fermentation and it was observed that this increase generally became greater as the rate of fermentation increased. The two ciders 65 and 74, which had high rates of fermentation each had an increase in total acidity only slightly greater than that of cider 53 which had a much lower rate of fermentation. This is in accordance with the graph (not included here), the slope of which decreased as the rate of fermentation increased.

The pH values of juices and ciders were determined electrometrically (Cambridge pH-meter) and in Table II are corrected to 0·05 pH unit. The pHs. of the Yarlington Mill juices varied only slightly (3·85 to 4·10) ; the pHs of the ciders varied rather more (3·45 to 3·95). In the Medaille d'Or series the pHs of the juices varied from 4·10 to 4·45 and of the ciders from 3·70 to 4·35. The pHs of the ciders were lower that those of the corresponding juices (exceptions 67 and 98) and this could be correlated with the greater acidities of the ciders.

The average pH of the Medaille d'Or juices (4·24) was higher than that of the Yarlington Mill juices (3·97). This was somewhat unexpected as the average total acidity of the Medaille d'Or juices (0·22%) was rather greater than that of the Yarlington Mill juices (0·19%). This apparent anomaly may probably be attributed to the different ash contents of the juices of the two varieties. Ash was not estimated in these samples but in former years juices of the Medaille

d'Or variety had an appreciably greater (26%) average ash content than those of the Yarlington Mill variety.

Tannins.

Estimation of the tannins in apple juice is a difficult and time-consuming process. The Lowenthal method adopted here, in which the cider (or juice) is titrated with $KMnO_4$ (0·785 g./litre) in the presence of indigo-carmine as indicator, is that usually employed. This titration gives a measure of the total permanganate-reducing substances present rather than of the tannins themselves (*13, 14*). It is hoped that a more satisfactory method of estimation of tannins may be used in subsequent work.

The "tannin" contents in the Yarlington Mill juices (Table II) ranged from 0·23%–0·56% (usually 0·23%–0·32%) and were abnormally low for the variety. Corresponding figures for the Medaille d'Or juices were higher and ranged from 0·36%–0·51%. The "tannin" contents of the ciders in each group were substantially lower than those of the corresponding juices. As indicated above the results for "tannins" are only approximate and are almost certainly higher than the real values.

Vitamins of the B_2 Group.

In an accompanying paper Mrs. James has reported (*15*) on the vitamin content (four components of the vitamin B_2 group) of ciders of different classes. Of the twelve Yarlington Mill and Medaille d'Or ciders considered in this paper three (Nos. 66, 74 and 96) were included in those (also twelve in number) assayed for their vitamin B_2 content, and the results are of sufficient interest to justify their inclusion here. (Table IV).

TABLE IV.

Vitamins of the B2 Group in Three of the Ciders.

Variety	No.	Riboflavin μg./100 ml.	Nicotinic Acid μg./100 ml.	Biotin μg./100 ml.	Pantothenic Acid μg./100 ml.
Yarlington Mill	66	nil	45	0·59	60
	74	18·0	185	1·34	168
Medaille d'Or	96	4·0	60	0·46	130
Average*		8·8	68·7	0·43	105

* These are the averages of the vitamin contents of the ciders examined for these constituents by Mrs. Dilys James (see accompanying paper).

Results. Cider 74 contained relatively large amounts of each of the four vitamins and, in fact, the amounts of riboflavin, nicotinic acid and biotin present in this cider were the greatest recorded for any of the twelve examined for vitamin content. In contrast, cider 66 contained relatively small amounts of three of the vitamins although its biotin content was above the average of the twelve.

The amounts of nicotinic acid, biotin and pantothenic acid in cider 96 were near the average ; its riboflavin content was comparatively small.

Since assays of the Vitamin B_2 content have been made on three only of the twelve ciders under discussion in this paper, a more detailed consideration of their vitamin content is not justified.

CRITICAL SAMPLING OF THESE CIDERS.

These observations were made on different samples from those used for all the chemical estimations, which were started about five weeks later. Corresponding ciders in these *two* replicate sets of bottles differed somewhat in their specific gravities (Table II) due to the variable amount of fermentation which had occurred. When such differences were observed, the cider used for sampling had a rather higher specific gravity (except 68) than the corresponding cider used for chemical analysis ; these variations were relatively large (4 degrees or more) for ciders 64, 96, 66 and 65 and was considerable for cider 74. The following observations refer to the ciders at the specific gravities as recorded in Table II. The variations between the specific gravities of replicates of a sample are discussed later.

Sampling observations on these ciders were made by a tasting panel of four and the tests were carried out even more exhaustively than as described in 1945 (*1*). It is peculiarly difficult to describe exactly the organoleptic character of different ciders in such a way as to indicate small differences between closely related samples. In an attempt to do this the system of using a numerical scale, as in 1945 for assessing the gas contents of ciders, was extended to other characters—clarity, colour, intensity of aroma, intensity of flavour and " body ". A full description of each of the twelve ciders in all these respects would be very lengthy and is not included here. These observations, however, were critically reviewed in a comparative manner at the time of sampling, and each cider was awarded a figure of merit (maximum 5.) The more important characters of and differences between individual ciders in each of the two groups are summarised below.

Yarlington Mill Ciders. All seven samples were of good clarity and the deposits were not abnormal in character or amount. With the exception of cider 67, which was moderately carbonated, the degree of carbonation was high, especially in 65 and 73. The colour of these ciders was typical of the class but the *intensity* of colour was variable ; 67 and 65 were medium to high in colour, 74 was medium, 66, 68 and 73 were rather below medium and 53 was much paler than is usual for this variety.

Aroma. The intensity of aroma varied considerably ; it was highest in 73, lowest in 66 and was moderate in all the others. In character all were of the bittersweet type, clean and, with the exceptions of 53 and 65, had distinct fruitiness ; 67 was outstandingly rich in aroma.

Flavour. Briskness on the palate was the outstanding feature of this group of ciders—a rather unexpected finding as the original juices were mostly of low acidity. Briskness was most pronounced in 65, 73, 74 and 53, and least pronounced in 68. The bittersweet character of the ciders as a group was low for the variety, ranging from mild to very mild, and only in 65 could it be regarded as medium. All the ciders were medium-sweet on the palate with the exceptions of 66 and 68 which were sweet. The greater apparent sweetness of these two ciders as compared with others of the group may possibly be attributed to their lower acidities. When fruitiness was detected it was present both in the aroma and flavour. " Body " was medium in 67, 73 and 74,

rather high in the others, and was high in 53. Intensity of flavour was rather greater than medium and was remarkably uniform throughout the series, but was only medium in 73. The softness of the ciders was, in general, of medium intensity ; 68 was soft, 66 rather less soft and 65 tended to hardness.

This group of ciders was above the average in quality even for the variety (see figures of merit in Table II). Ciders 68 and 66 were the best, and all the others were highly placed, except 67 which was rather less attractive. This latter cider was marked down on account of a slight staleness in its flavour but in all other respects was of high quality.

Medaille d'Or Ciders. All five samples were of excellent clarity with normal deposits, and were rather less carbonated than the Yarlington Mill ciders, with the exception of 96 which was highly carbonated. The colour of these ciders was typical of the class and was uniformly medium to high in intensity, with the exception of 96 which was rather less than medium.

Aroma. Intensity of aroma generally was high, especially that of 64. In character, all were bittersweet and, with the exception of 63, were clean and fruity. In three of the samples (64, 97 and 98) there was an additional feature described as " scented ", a quality which has previously been observed in ciders of this variety ; these three ciders may be described as possessing a definite bouquet. Cider 98 was noteworthy in that its aroma was somewhat vinous in character. The aroma of 63 was slightly yeasty.

Flavour. The bittersweet character of these ciders was unusually high but was typical for the variety ; this quality was especially marked in 63 and 96. In contrast with the ciders of the other group, briskness was lacking in all these samples except 63. Sweetness was variable—97 and 98 were sweet, 63 and 64 were medium sweet and 96 was medium dry. Cider 98 was rather too sweet and this quality was expected from its abnormally high specific gravity—1036 at time of sampling. The explanation of the abnormally high specific gravity of this cider has already been given. All the samples were noticeably alcoholic especially 64, 97 and 98, which in addition had a vinous character. Fruitiness was apparent only in 98, and to a lesser extent in 64. In all ciders except 96 body and intensity of flavour were above normal and were especially full in 64, 97 and 98 ; 96 was rather thin and had little flavour other than the intense bitterness of the tannins. These ciders (except 96) were soft on the palate, especially 98.

As a group these ciders were excellent and the three best, in order of merit 97, 98 and 64, were outstanding.

THE INFLUENCE OF SITE AT WHICH THE FRUIT WAS GROWN ON THE CHARACTER AND CHEMICAL COMPOSITION OF THE JUICES (AND CIDERS).

Investigation of the influence of site on the composition of the fruit grown at that site, is a subject that is under continual investigation at this Research Station. During the last few years the work has been mainly concerned with fruit grown on bush trees (*16*, *17*, *18*) and bush fruit grown at the sites mentioned in the present paper has been examined. The fruit from which these ciders were made was grown on bush trees at widely different sites. These trial orchards are situated in the counties of Hereford, Worcester, Gloucester, Somerset, Devon and Kent and are described by Swarbrick (19). All trees in these orchards were raised in the nursery at this Research Station and were reasonably uniform in character at the time of planting. It is reasonable

therefore to attribute differences in juice composition to the influence of the various factors associated with site, e.g. soil, climate and management. These factors cannot be considered separately in this paper and the influence of site is treated in a general way. Some of the more important properties of these twelve juices and ciders will now be considered in relation to site.

Nitrogen. As in former years, fruit from Poundisford yielded low-nitrogen juices and Compton Greenfield now appears also to be a low-nitrogen site. For example (1) juices 66 and 67, with the two lowest nitrogen contents in the Yarlington Mill series, were derived from fruit grown at these two sites and (2) juice 98, with the lowest nitrogen in the Medaille d'Or series, was from Poundisford (no juice was available of the variety Medaille d'Or from Compton Greenfield). In accordance with their low nitrogen content, these three juices 66, 67 and 98 had low rates of fermentation. Fruit from Hereford and from Faversham yielded juices (74 and 65) with the two highest nitrogen contents in the Yarlington Mill series and these two juices had high rates of fermentation ; the juice of the Medaille d'Or variety from Faversham was moderately high in nitrogen. In former years fruit from Much Marcle has yielded high-nitrogen juices ; of the juices from this site now under consideration, the Medaille d'Or (64) was the highest in nitrogen in the series but the Yarlington Mill juice did not have a high nitrogen content in comparison with the others of this variety.

Specific Gravity of the Juices. Fruit from the Poundisford centre yielded the juices with the highest specific gravity in each variety ; the high specific gravities of juices from this centre has also been observed in former years. In the remaining six Yarlington Mill juices there was little variation in specific gravity. All the Medaille d'Or juices had a high S.G., especially juice 98 (Poundisford) and 97 (Newnham Bridge). In this connexion it should be borne in mind that all fruit, prior to milling and pressing, was stored in open trays in the cider-house and, in a late maturing variety such as Medaille d'Or, the desiccation which occurred may have been appreciable and somewhat variable in extent. It is possible therefore that the very high specific gravities recorded for juices 87 and 98 may have been rather higher than the true values.

Tannins. Fruit of the Medaille d'Or variety from all five sites yielded juices with high " tannin " contents, as expected for the variety. Juice 64, which had the lowest " tannin " in the series, was derived from fruit grown at Much Marcle. This site was also the origin of the juice with the lowest " tannin " content in the Yarlington Mill series. In contrast, fruit from Poundisford and Hereford yielded high " tannin " juices of both varieties ; the Yarlington Mill juice (Poundisford) had a "tannin" content which was considerably higher than that of any of the other six juices of this variety.

Total Acidity. The titratable acidity of the juices showed little variation and no useful correlation could be drawn between total acidity and site at which the fruit was grown. Attention may, however, be directed to the high acidity of juice 67 of the Yarlington Mill series which was considerably greater than that of any other juice of this variety ; this juice was derived from fruit grown at Poundisford.

Volatile Acidity, Esters and Aldehydes. In preceding paragraphs, site has been considered in relation to constituents of the *juices*. Determinations of volatile acidity, esters and aldehydes were made on the *ciders* and, while it is realised that some of these substances may have been present in the fresh juices, they are probably to be regarded mainly as products of fermentation. Close correlation between the concentrations of these constituents in the cider

and the site at which the fruit was grown is therefore not necessarily to be expected. Certain observations may however be made. In both varieties, the ciders with greatest concentrations of these substances were made from fruit grown at the Poundisford and Hereford sites ; the Faversham site yielded ciders which contained very little of these substances.

Vintage Quality of the Ciders. It was difficult to associate high quality in a cider with a particular site, partly because the ciders of these two groups were of high merit and differences in quality were small. As in previous years the fruit of each variety from Poundisford and from Compton Greenfield yielded ciders of very high quality ; the reason for the relatively low merit awarded to Yarlington Mill Cider 67 (Poundisford) has previously been explained. One (98) of the two Medaille d'Or ciders which were outstanding in merit was made from Poundisford fruit, the other (97) was made from fruit grown at Newnham Bridge ; there was no cider of this variety from Compton Greenfield.

DISCUSSION.

The two groups of ciders examined were typical of the bittersweet class and were prepared from fruit grown on bush plots at different sites. The making of the ciders proceeded normally and calls for little comment apart from (1) the abnormally low temperatures which retarded the fermentation of some of the juices, especially of three of the Medaille d'Or variety and (2) the occurrence of the phenomenon of " dropping-bright " during the fermentation of juice 64. As the ciders were required in a naturally sweet condition, fermentation was stopped by filtration at S.G. 1025 approx. Filtration at this comparatively high specific gravity interferes with the normal course of the primary fermentation and, in so doing, will also materially influence the nature and extent of the fermentation and other changes which take place " in bottle ". Although only twelve ciders have been examined, many different properties have been considered and, in view of the wide field covered, the work described in this paper must be regarded as *preliminary in nature and indicative of future research.*

Previous workers at this Research Station have shown that the nitrogen content of a juice plays a dominating part in its fermentation (*20*, *21*) and the present investigation of the role of nitrogen has also proved fruitful. Thus, the rates of fermentation of these twelve juices have been shown to be directly related (1) to the total nitrogen of the juices and (2) to the " nitrogen used per 10° decrease in specific gravity " (primary alcoholic fermentation). These correlations were well demonstrated by the data for the Yarlington Mill juices.

In this study of the role of nitrogen in fermentation, attention has also been directed (1) to the smallest amount of nitrogen required for fermentation to proceed under the conditions of these experiments and (2) to the proportion of the total nitrogen of a juice which is available to the yeasts. Both these aspects are of fundamental importance and, although it has been possible to give some indication of the magnitude of these factors, much further work is required before more precise statements can be made.

In previous years rate of fermentation has been determined by removing a portion of the fresh juice and incubating at 25°C (*20*). In this investigation, rate of fermentation was determined on the total bulk of fermentating juice at cider-house temperatures. The relative merits of these two methods of determining rate of fermentation will be discussed in a subsequent paper.

The alcohol contents of these ciders require little comment. Estimations

of the alcohols were made by a chemical method ; this method is specific for alcohols and any alcohol which may be present would be estimated as ethyl alcohol. No information is at present available concerning the amounts of any alcohol, other than ethyl, which may have been present in the ciders.

Consideration of the volatile constituents other than alcohol, in cider, is necessarily limited by the lack of published data. No information has been found in the literature concerning the ester and aldehyde contents of normal ciders, although Warcollier (*22*) mentions the presence of amyl esters of formic, acetic and caproic acids (and of traces of the amyl ester of caprylic acid) in apple juice together with appreciable quantities of acetaldehyde. The amounts of esters found in these ciders were low and were much lower (except in 98) than those reported by Ribéreau-Gayon and Peynaud (*6*) as normally present in wines ; the aldehyde contents of the ciders were however of the same order as in the wines.

When an attempt was made to correlate the concentration of the esters and aldehydes present in a cider, with a quality such as aroma it was found that the three ciders, 64, 97 and 98, which had been described as having a bouquet, had relatively large amounts of these constituents. Other ciders however (e.g. 96, 73 and 66) also contained comparable amounts of both esters and aldehydes but were not particularly attractive in aroma. The former three ciders, 64, 97 and 98, were those of outstanding merit (Table II). The need for a more precise method of estimation of small amounts of esters has previously been indicated.

The volatile acidities of the twelve ciders (except 67) were low and all were below the level of 0·2%, the permissible maximum in ciders qualifying for the National Mark, under the pre-war National Mark Scheme. The correlation observed between rates of fermentation and the volatile acidities of the Yarlington Mill ciders, namely, that volatile acidity tended to increase as the rate of fermentation decreased, is of particular interest. When sampling, no trace of acetification was detected in any of the twelve ciders. The volatile acidities of the juices were not estimated.

The *total acidities* of these ciders were of special interest in several important respects. In particular, each of the twelve ciders (except 98) had a greater total acidity than that of the corresponding juice. These results were entirely unexpected and were not in agreement with those recorded by earlier workers e.g. Lloyd (*23*), Grove (*24*). These workers show that total acidity usually increases during the primary fermentation, as would be expected, and the cider at filtration therefore has a greater acidity than the fresh juice ; a decrease in total acidity then occurs during the period of storage in the bottle and the resulting acidity of the cider is usually lower than that of the fresh juice. The changes in total acidity which separately occurred in these twelve ciders (a) prior to filtration and (b) during storage in the bottle are not known, because the acidities of ciders at time of filtration are not normally determined (see introduction). It can however be stated that there was no reason to suspect that any undesirable bacterial fermentation had taken place " in bottle " in any of these high quality ciders.

As described above, the analytical data relating to the total acidities of the ciders and juices recorded in this paper differs fundamentally from that of the earlier workers and it is important that the reasons for the difference should be ascertained. Further investigation of the changes in acidity which occur during the primary fermentation and during fermentation " in bottle " is obviously required. Certain facts relevant to these problems may however

be stated at this early stage. Thus, there were important differences between our technique and that of the earlier workers. For example, the ciders described by Grove were prepared on a relatively large scale from juices which were fermented in *wooden* vessels, and the ciders were probably filtered through a pulp filter. In our experiments the juices were fermented in small bulk in *glass* vessels and the ciders were filtered through kieselguhr by means of a Meta-filter (*1*). It is reasonable to assert that this latter method of filtration is more efficient than filtration through a pulp filter and we have found this to be so in other experiments. The number and nature of the micro-organisms remaining in the filtered cider would differ according to the method of filtration employed. When the difference between fermentation in glass vessels and fermentation " in the wood " is considered many points of interest arise. It has formerly been believed that wooden vessels are desirable as containers of fermentating apple juices (and of other juices as in the preparation of wines). The quality of the twelve ciders under investigation was unusually high, especially that of the Medaille d'Or ciders and was, in fact, one of the reasons why they were selected.

Although the relative importance of the factors discussed in the above paragraph cannot be assessed at this stage, it will be obvious that they are important and require further investigation ; this may lead to results of great practical value.

A factor which must be considered in relation to the fermentation and other changes which take place " in bottle ", is the presence of small amounts of sulphur dioxide. As stated earlier, the bottles and corks used in the processing of these twelve ciders were sterilised with SO_2. The small and somewhat variable amounts of SO_2 thus introduced into the ciders, were insufficient to affect significantly the analytical data recorded in this paper, but may possibly have had some influence on the nature of the micro-organisms present in the bottle and on their activity. Grove does not mention the use of SO_2 in his experiments. This aspect of the work is under investigation.

One further point of interest in connexion with the total acidities of the juices and ciders may be mentioned in the Yarlington Mill series—correlation was observed between " increase in total acidity " and the rate of primary fermentation of the juice, the increase becoming greater as the rate of primary fermentation increased. This relationship is opposite in nature to that observed between rate of fermentation and volatile acidity, since the latter decreased in magnitude as the rate of fermentation increased. The significance of these relationships cannot be explained with the data at present available.

The " tannin " contents of the ciders were apparently lower than those of the corresponding juices. Little significance can be attached to these results since the method of estimation employed is not specific for tannins and there is a need for an improved method of estimation. Four of the five Medaille d'Or juices and the Yarlington Mill juice 67 contained relatively large amounts of tannins (more than 0·4%) and it is possible that the low rates of fermentation of these juices may have been due in part to the restrictive action of their high tannin contents on fermentation since tannins are said to exert such an effect (*25*). The fermentation of these four Medaille d'Or juices however, may have been slowed down appreciably by the relatively large amounts of alcohol formed and also by the abnormally low temperatures at which three of the juices were fermented. Further analytical data is required before the effect of tannin on fermentation can be evaluated.

The vitamin (B_2 group) contents of three of these ciders are recorded, but

with so few results available further comment is not justified at present. The vitamin (B_2 group) contents of a series of ciders are discussed by Mrs. James elsewhere in this journal.

The amounts of total residual " sugars " in these ciders are not included as it was not practicable to carry out the estimations on the *single* sample of each cider used for the chemical estimations.

When this work was started one of its objects was an attempt to relate the qualities of a cider as a beverage with its chemical composition. This can better be achieved when analytical and other data for additional ciders becomes available, rather than with the somewhat limited data provided by this preliminary survey. Certain relevant observations may however be made. A cider is usually assessed primarily according to its specitic gravity and its contents of tannin, acid, sugar and alcohol ; when blending is required, the balance of these constituents is adjusted in order to produce a satisfactory cider. Detailed discussion of the sugar/acid/tannin ratios cannot be made here but the data relating to the acid/tannin ratios is available in the tables and in the section describing the critical sampling. The desirable quality of fruitiness observed in some ciders is associated with small amounts of constituents such as volatile acids, esters and aldehydes, although other substances may also be involved. It was, in fact, possible to relate the bouquet which was observed in three of the ciders with their contents of esters and aldehydes (see however the early part of this discussion).

In concluding this brief discussion of some of the relationships which are possible between the organoleptic qualities of a cider and its chemical composition, mention may be made of an interesting correlation which was observed between the pH of a cider and its degree of briskness on the palate. This rather elusive quality, which was an outstanding feature of the Yarlington Mill ciders, is difficult to define although it is known that total acidity is not the only factor concerned. It was observed that those Yarlington Mill ciders in which briskness was most pronounced had relatively low pHs and the cider with the least briskness had the highest pH of the series. Also, the only Medaille d'Or cider described as brisk had the lowest pH of the ciders of this variety. It is possible that this correlation might have been carried further if the assessment of briskness in these ciders had been sufficiently detailed.

The influence of the locality at which the different samples of fruit were grown upon the composition of the juices and ciders and upon the vintage quality of these twelve ciders is described in this paper. It is not intended to attempt to relate these findings to any of the separate factors which determine the influence of site.

As already stated it was not practicable to use a single sample of each cider for all the observations described in this paper and two replicates of each sample were used. Sampling tests were made on one of these replicates and, it is necessary to emphasize that all the chemical analyses were carried out on the other i.e. on a single sample of each cider. In the section on critical sampling it was shown that unexpected differences existed between the specific gravity of the replicate used for sampling and that used for chemical analysis and that these differences were sometimes relatively large. Similar differences in specific gravity were observed when a third replicate of each sample was opened. The two replicates of each of the twelve ciders used respectively for sampling and for chemical analysis had been opened within a time interval of five weeks only and, as the storage in bottle was of 10–15 months duration (a longer storage than usual) the small differences in the storage times of different

replicates could not possibly account for the variations observed between the replicates. It is of the utmost importance that the reasons for these variations should be ascertained and the variations themselves reduced to a minimum. In order to do this the conditions under which the ciders were prepared and bottled (especially the latter) must be closely examined. These experimental ciders were prepared under carefully controlled conditions as described by Barker and Burroughs (*1*) and, as recommended by these authors, the ciders were filtered through a Meta-filter. When the filtrate had become quite clear and was apparently homogeneous, i.e., when its specific gravity was the same as that of the unfiltered cider, bottling was commenced *direct* from the filter. It was believed that this procedure would give a homogeneous filtrate but, it now seems possible that there may have been some lack of uniformity in the number of micro-organisms present in different parts of the filtrate and therefore in different replicate bottles of a sample of cider. Variations in the extent of the fermentation and other changes which occurred in the different replicate bottles of a sample would then be expected and the variations which have, in fact, been observed would thus be explained. It has already been suggested that variations in the amounts of sulphur dioxide might influence the extent of the fermentation which takes place in the bottle. Further work, however, is required before these variations between replicates of a sample can be fully explained.

The analytical data presented in this paper must now be considered in relation to these variations. Since they did in fact occur it must be concluded (1) that these data are strictly relevant to a single replicate of each sample of cider and not necessarily to the sample as a whole, (2) that the technique of bottling of these twelve ciders, although it followed a procedure which had hitherto been considered satisfactory, must be still further improved.

It follows from the first of these conclusions that, if the average chemical composition of any one of these twelve ciders is required in respect of the constituents described in this paper, then analyses must be made of more than one of the replicates of the sample of the cider. The analytical data presented in this paper are, to this extent, limited in their application ; their value is however considerable since they characterise twelve ciders at known specific gravities.

The second of the important conclusions described above, namely the need for improvement in bottling technique, and possibly in the filtration prior to bottling, focusses attention upon the need for knowledge of the changes which occur in the cider during storage in the bottle. It is obvious that, in order to study the chemical changes involved, analytical data *at the time of filtration* (prior to bottling) as well as at the end of the storage period will be required. The need for estimation of nitrogen and total acidity at time of filtration has already been clearly demonstrated. Extension of these analyses to include estimation of some of the constituents—tannins, sugars, alcohols and other volatile constituents is required. Consideration of such analytical data, and of data on the finished cider as provided by the present investigation, will materially increase our knowledge of the changes which occur while the cider is in the bottle.

In conclusion it may be stated that this *preliminary investigation* of the chemistry of two groups of bittersweet ciders has produced many interesting results. It has revealed the need for further work on a number of aspects which are of importance in different processes associated with the *making of cider*, and has indicated directions in which this research may most profitably

be pursued. Further work on the more important of these aspects may well lead to results of considerable practical value.

SUMMARY.

1. Two groups of bittersweet ciders (varieties Yarlington Mill and Medaille d'Or) were prepared on an experimental scale.

2. The influence of the nitrogen contents of the juices on fermentation was examined with particular reference to rate of fermentation.

3. Certain constituents in the twelve ciders were estimated :—nitrogen, total acidity, " tannins ", alcohols ; volatile substances other than alcohols i.e. volatile acids, esters and aldehydes. Estimations of nitrogen, total acidity and " tannins " in the juices were also carried out. The pHs of the juices and ciders were determined.

4. Comparisons were made between the amounts of these constituents present (a) in single replicates of a sample of each of the ciders in a group and (b) in the one group of ciders as compared with the other.

5. Significant variations in the specific gravity of replicate bottles of a sample of cider were observed.

6. The contents of riboflavin, nicotinic acid, biotin and pantothenic acid in three of the ciders are recorded.

7. The influence of the site at which the fruit was grown upon the chemical composition of the juices (and therefore of the ciders) was examined.

8. Some of the possible correlations between the organoleptic qualities of the ciders and their chemical composition are discussed.

9. The value of analytical data at the time of filtration (prior to bottling) is emphasized. Other suggestions for future research are made.

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SOME VITAMINS OF THE B GROUP IN CIDER.

By DILYS P. JAMES

Random samples of cider assayed during the past three years were found to contain riboflavin in amounts ranging from 6 μg. to 17 μg./100 ml. of cider in screw-stoppered bottles, the average being 7·5 μg./100 ml. Seitz-filtered ('vintage') cider contained rather less, averaging 5 μg./100 ml., and perry 6 μg./100 ml.

During the 1947 season investigations of three other members of the B group of vitamins were begun in fruits and it was thought that extension of this work to ciders would prove interesting. Accordingly in December, 1947, twelve ciders were assayed for riboflavin, nicotinic acid, biotin and pantothenic acid.

The ciders selected had been prepared in 1946 by the method described by Challinor & Burroughs (1). Six varieties of apple were used, each providing two batches of cider, the two samples of each variety being obtained from different localities. Fermentation of the pressed juices was by natural wild yeast only.

Method of Assay.

A microbiological method of assay was used for each of the four substances (2).

Many bacteria can be cultivated in simple artificial media because they are able to synthesise the vitamins and amino acids that they need. Others have lost this power and such requirements have to be supplied by the medium in which the organism is growing. When one essential vitamin or amino-acid is omitted from the medium, all others being in adequate supply, the response of certain organisms to additions of the missing ingredient is quantitative. Such organisms are employed as test organisms in microbiological assays.

The principle upon which all assays of this kind are based is the preparation of a basal medium containing ample amounts of all the essential requirements for growth of the organism, except the one to be determined. Graded doses of the specific nutrient to be assayed are added to this medium, the subsequent growth or production of lactic acid being proportional to the concentration of the essential metabolite added. A parallel series of tubes containing the basal medium plus test material is prepared at the same time. After incubation the response obtained in the two series is compared.

Lactobacilli were employed as the test organisms in assays of the four vitamins considered here. For riboflavin assay a tested strain of *L.helveticus* was used, and assays of nicotinic acid, biotin and pantothenic acid were made with *L.arabinosus*. In all cases response was measured by titration of the lactic acid produced. Preliminary tests showed no differences between results obtained when the ciders were autoclaved with acid or subjected to enzyme digestion prior to assay, and those when such hydrolysis was omitted. The normal practice here of shaking fruit extracts with chloroform before assay (3) was found to be necessary for the assay of riboflavin in cider but immaterial to nicotinic acid, biotin and pantothenic acid assays. This sensitivity of *L.helveticus* compared with that of *L.arabinosus* has been demonstrated by many other workers.

The following routine procedure was conveniently adopted. The filtered de-gassed cider was shaken with chloroform and centrifuged. The pH of a 50 ml. portion of the supernatant was adjusted to 6·8 against bromo-thymol-blue, and dilution to 200 ml. made.

For assay of riboflavin and nicotinic acid suitable volumes of this extract were transferred to fermentation flasks containing 5 ml. of the appropriate, double strength, basal medium (2). The aliquots were chosen to give levels between 0·03 and 0·15 μg. of riboflavin per flask for riboflavin assay, and for assay of nicotinic acid between 0·05 to 0·2 μg. of nicotinic acid per flask.

For assays of biotin and pantothenic acid the extract was further diluted ten times. Aliquots were taken for assay to give levels between 0·00003 and 0·00015 μg. of *dl* biotin/flask, and from 0·005 to 0·2 μg. of pantothenic acid/flask.

The total volume in each flask was adjusted with distilled water to 10 ml. Fermentation and subsequent titration were carried out in conical flasks of total capacity 50 ml. (3). Inoculations with washed suspensions of the appropriate organism were made from shielded, sterilised burettes. The flasks were incubated for 72 hrs. at 30°C for assays of biotin and pantothenic acid, and 37°C for riboflavin and nicotinic acid. For assay of each substance the usual range of standards was prepared, in each case assay of the pure vitamin being made at seven levels of concentration. Each test preparation was assayed at at least three levels and all estimations were made in triplicate.

Results.

Results of typical assays on a single cider are shown in Tables I—IV. Response in riboflavin and nicotinic acid assays gave linear standard and test preparation curves. The slope ratio method of computation was thus used for calculation of results which agreed closely with those obtained by direct reading from the standard curve. In assays of biotin and pantothenic acid the 'single curve' method only could be used, there being no true linear portions of the standard curves.

The riboflavin, nicotinic acid, biotin and pantothenic acid contents of the twelve ciders examined are given in Table V. Information concerning the variety of apple and locality in which it was grown are shown for each cider, together with the rate of fermentation and nitrogen content of the pressed juice. In order to correspond with tables in the paper by Challinor and Burroughs (1), the ciders have been arranged according to their fermentation rates. For ciders 62 and 78 no figures for fermentation rates were known, their positions in the table being thus approximate. The methods used in estimating nitrogen contents and rates of fermentation at cider house temperatures have already been described (1).

DISCUSSION.

Microbiological methods of assay have proved eminently satisfactory for estimation of riboflavin, nicotinic acid, biotin and pantothenic acid in ciders. Lack of interference by other cider constituents enabled pre-assay treatment to be reduced to a minimum. One extract only was required for assay of all four vitamins in each cider, and the four assays could be carried out simultaneously with ease.

The ciders differed widely in the amounts of these four substances which each contained. Ranges obtained were 0 to 18 μg. of riboflavin, 31 to 185 μg. of nicotinic acid, 0·15 to 1·34 μg. of *d* biotin and 0 to 198 μg. of pantothenic acid in 100 ml. of cider.

TABLE I.

RIBOFLAVIN.

Dose	Cider 31 diluted 1 in 4 ml.			Standard Curve Riboflavin μg.						
	1	2	3	0	0·05	0·07	0·1	0·15	0·2	0·25
Mean response ml. approx. 0·1 *N* NaOH	1·34	1·96	2·61	0·69	1·58	1·9	2·46	3·3	4·15	4·85
Riboflavin μg./100 ml. From single curve	14·7	14·6	14·8							
By slope ratio		14·7								

TABLE II.

NICOTINIC ACID.

Dose	Cider 31 diluted 1 in 4 ml.			Nicotinic acid μg.					
	0·4	0·6	0·8	0	0·05	0·1	0·15	0·2	0·25
Mean response ml. approx. 0·1 *N* NaOH	2·08	2·66	3·22	1·18	2·22	3·49	4·79	6·18	7·58
Nicotinic acid μg./100 ml. From single curve	44	45	45						
By slope ratio		45							

TABLE III.

BIOTIN.

Dose	Cider 31 diluted 1 in 40 ml.			*dl* Biotin μg.				
	0·4	0·6	0·8	0	0·0001	0·00015	0·000175	0·0002
Mean response ml. approx. 0·1 *N* NaOH	3·05	3·69	4·43	1·42	4·0	4·97	5·49	5·75
d Biotin μg./100 ml.	0·29	0·28	0·3					

TABLE IV.

PANTOTHENIC ACID.

Dose	Cider 31 diluted 1 in 40 ml.			Pantothenic acid μg.					
	0·2	0·4	0·6	0	0·005	0·01	0·02	0·04	0·06
Mean response ml. approx. 0·1 *N* NaOH	3·27	3·92	4·57	2·3	3·54	4·22	5·65	7·45	8·8
Pantothenic acid μg./100 ml.	82	75	78						

TABLE V.

Cider	Variety	Locality	Rate of Fermentation	Nitrogen mg./100 ml.	Riboflavin μg./100 ml.	Nicotinic Acid μg./100 ml.	*d* Biotin μg./100 ml.	Pantothenic Acid μg./100 ml.
*74	Yarlington Mill	Hereford	8·9	10·24	18·0	185	1·34	168
99	Medaille d'Or	Compton Greenfield	8·6	4·4	10·0	100	0·67	160
30	Kingston Black	Much Marcle	8·5	8·31	12·5	31	0·16	140
62	,, ,,	Faversham	Rapid	14·61	11·0	66	0·31	184
75	Sweet Alford	Hereford	6·6	8·99	5·0	44	0·17	142
31	Stoke Red	Much Marcle	4·9	4·85	14·7	48	0·27	79
*96	Medaille d'Or	Hereford	4·07	13·58	4·0	60	0·46	130
100	Dabinett	Poundisford	3·98	4·51	12·0	44	0·26	0
88	,,	Much Marcle	3·7	15·21	12·0	101	0·56	198
78	Sweet Alford	Poundisford	slow	2·82	6·4	56	0·15	0
*66	Yarlington Mill	Compton Greenfield	2·2	3·34	0	45	0·59	60
55	Stoke Red	Poundisford	1·1	2·08	0	44	0·17	0
Average			5·26	7·83	8·8	68·7	0·43	105

* Included in twelve ciders discussed by Challinor and Burroughs (1).

All three varieties of apple grown in the Poundisford district gave juices with low nitrogen contents and fermentation rates, and ciders which were below average in nicotinic acid and biotin and completely lacking in pantothenic acid. The soil in that district was known to be low in nitrogen, but so was that at Compton Greenfield and ciders from apples grown there varied : one (66) was also slow to ferment and below average in nitrogen and the four vitamins, the other (99) having a low nitrogen content but comparatively high values for all other factors. No other relevant details of the two localities were available. It is interesting to note that of the varieties grown at Poundisford, Stoke Red and Dabinett were also obtained from Much Marcle and these ciders contained fair proportions of pantothenic acid, as did the cider of the third variety, Sweet Alford, from Hereford. The soils at Hereford, Much Marcle, and Faversham were high in nitrogen.

In general there appeared a tendency for juices with high nitrogen contents to give ciders high in pantothenic acid, and juices with nitrogen contents below average, ciders comparatively low in pantothenic acid. Cider 99 alone proved an exception to this trend, but its rate of fermentation was particularly rapid and the fact that the initial gravity of the juice was outstandingly high, may have some significance.

One other point is perhaps worthy of attention. Primary fermentation of the juices took place in jars of colourless glass in a store lighted by a window facing south. Subsequent storage was in bottles of brown or green glass. In most cases the juices which were slowest in fermentation were exposed to light for the longest periods. This may account for the complete absence of riboflavin in ciders 66 and 55, in which fermentation was extremely slow and exposure to light therefore long, being 76 and 187 days respectively, compared with 22 days for cider 74 and 34 days for cider 31.

The range of riboflavin values in the twelve ciders was similar to that found in the large number of ciders previously assayed, though all of these contained some riboflavin. It is probably significant that the normal practice of fermentation in casks had been followed for these ciders so that there was no undue exposure to light. As most yeasts are able to synthesise members of this group of vitamins it is not surprising that the Seitz filtered ciders contained less riboflavin than the ciders filtered through paper pulp. No details were available of the yeast flora of the ciders during fermentation and storage, nor of the apples from which they were made.

SUMMARY.

Values are given for riboflavin contents of cider and perry.

Riboflavin, nicotinic acid, biotin and pantothenic acid have been estimated in twelve ciders prepared from six varieties of apple grown in five localities. It is impossible to draw conclusions from the limited number of samples assayed, but certain tendencies are indicated.

Some details are given of the methods of microbiological assay used ; their suitability for the simultaneous estimation of these four substances is demonstrated.

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FACTORS AFFECTING JUICE COMPOSITION AND CIDER QUALITY OF FRUIT FROM BUSH TREES.

I. THE EFFECT OF COVER-CROP AND ROOTSTOCK ON THE COMPOSITION OF THE JUICE.

By L. F. BURROUGHS and W. R. STANTON.

The bush cider apple plot (Plot 20) at Long Ashton was planted in 1935–36 as part of a series of such plots, described by Swarbrick (*1*) in the 1941 Annual Report. The general layout of this plot and its separation into two parts (A) and (B) have been described by Bould (*2*) together with details of the cover-crops applied to plot 20B and the effect of these cover-crops on the yield of fruit obtained in the season 1946. The present article considers the chemical analysis and other properties of the juices obtained from the 1946 crop of plot 20B : estimations of the yield of juice obtained from the different samples of fruit are also given. Appreciable crops were obtained in this year from the varieties Stoke Red, Sweet Alford and Dabinett.

EXPERIMENTAL TECHNIQUE.

A random sample of fruit of approximately 10 lb. was taken from each tree when the fruit was harvested ; dates of harvesting are recorded by Bould (loc. cit.) These samples were combined according to variety, plot and rootstock, making a total weight of about 60 lb. of fruit from a normal group of six trees. Samples from young trees (i.e. " replants ") and from trees with an abnormally light crop were excluded.

After a period of maturing in the cider-house, the fruit of each variety as it came to the required degree of ripeness was milled and pressed according to the method described in a previous article (*3*). No marked differences in rate of maturing were observed between different samples (i.e. differing in plot treatment or rootstock) of the same variety. Eighteen samples were obtained for each variety, derived from two rootstocks and nine plots ; the milling and pressing of these samples was necessarily spread over two days. The probable effect of this time difference on the composition of the juices is very small and furthermore is eliminated statistically (by confounding with the two blocks—Block II, treatments A_2 to E_2, were milled on the first day and Block I, treatments A_1 to E_1, on the second day).

The yield of juice obtained per ton of fruit is an important economic factor in cider-making, and it was therefore felt desirable to obtain data on the possible effect of cover-crop and rootstock in this respect. Direct measurement of the volume of juice expressed from a given weight of fruit is not reliable as a measure of the yield of juice obtained in this small-scale processing. The method adopted here was that previously described (*3*) and is based on the weight of the residual pomace obtained from a weighed quantity of fruit ; after applying a correction for the specific gravity of the juice, the yield is expressed in terms of gallons per ton.

The juice expressed from each 60 lb. of fruit was bulked and a sample ($2\frac{1}{4}$ gallons) was taken for cider-making trials. A further sample was taken for chemical analysis, the results of which form the material for this report. The vintage quality of the ciders prepared from the small-scale fermentations will be discussed in a later paper when more data are available to enable precise

conclusions to be drawn. The variations in chemical constitution of the juices however show sufficient significant differences in certain respects to warrant recording at this stage.

Chemical Analysis of the Juices.

The following determinations of certain chemical constituents and other properties were made on each juice ; a brief indication of the methods of determination is also given :—

1. *Specific Gravity* was determined by hydrometer.
2. The *Total Sugars* present in the juices were determined by the method of Lane and Eynon (*4*) following clarification with neutral lead acetate and inversion with HCl. Results are expressed as percentage of " invert-sugar " (g./100 ml.)
3. The *Total Acidity* of the juices was determined by the method described by one of the writers (*5*) and is expressed as percentage of malic acid (g./100 ml.)
4. The *pH* of the juices was determined electrometrically (Cambridge pH-meter) using a saturated calomel/glass electrode system.
5. The *Tannin* content of the juices was determined by a simple Lowenthal titration of 1 ml. of juice in 200 ml. of diluted indigo-carmine indicator with potassium permanganate (0·785 g./litre). It is very non-specific and represents " permanganate-reducing substances " rather than the true tannin content. Results are expressed in terms of an arbitrary tannin standard, as g. " tannin "/100 ml. of juice.
6. The *Rate of Fermentation* was obtained by incubating a sample of each juice at 25°C and determining its specific gravity at daily intervals down to an S.G. of approximately 1,010. The rate of fermentation is then expressed as the average number of degrees of S.G. lost per day by fermentation at a temperature of 25°C.
7. The *Total Nitrogen* content of the juices was determined by Kjeldahl digestion ; a Markham apparatus was used for the steam distillation of a suitable aliquot of the digest solution.

The results of these analyses have been treated statistically and certain correlations of variety, rootstock, or plot treatment with juice composition have been found ; these are described in the latter part of this paper. For reasons of space it is not possible to tabulate all the results (for three varieties, two rootstocks and nine plots) but an abbreviated table is given bringing together the means of the effects of plot treatment and rootstock on the composition of the juices of the three varieties (Table I.)

Treatment E (Perennial Rye Grass and White Clover) has been omitted from statistical considerations, since the plot is split between the two blocks and, unlike the other treatments, is not duplicated.

Statistical Comparisons.

Of the various determinations recorded in Table I, total nitrogen, total acidity and " tannin " content of the juices were found to show significant variations with different plot-treatments and rootstocks. Differences in yield, specific gravity and total sugar content could be correlated only with the variety.

TABLE I.

Variety	Treatment or Rootstock	Yield of Juice (gals./ton)	Specific Gravity	Total Sugars (as "invert" g./100 ml.)	Total Acidity (as malic acid g./100 ml.)	pH	"Tannin" (g./100 ml.)	Rate of Fermentation	Total Nitrogen (mg./100 ml.)
STOKE RED	A	176	1·0475	10·76	·633	3·12	·36	1·00	2·77
	B	177	1·0463	10·57	·626	3·12	·37	1·35	3·13
	C	176	1·0493	10·90	·661	3·19	·36	1·50	2·80
	D	178	1·0458	10·38	·595	3·15	·38	1·50	3·30
	E	169	1·0465	10·49	·643	3·09	·39	1·50	2·67
	Crab	174	1·0478	10·76	·625	3·15	·36	1·52	3·18
	M 1	177	1·0464	10·51	·635	3·12	·37	1·17	2·75
SWEET ALFORD	A	156	1·0650	14·57	·210	3·88	·21	6·15	10·79
	B	163	1·0658	14·76	·185	3·87	·21	6·93	11·17
	C	162	1·0638	14·69	·138	3·91	·21	6·35	9·37
	D	159	1·0663	14·80	·155	3·90	·21	6·63	12·49
	E	163	1·0610	13·26	·185	3·90	·19	6·25	10·26
	Crab	159	1·0645	14·47	·177	3·90	·21	6·61	11·59
	M 1	162	1·0649	14·72	·170	3·89	·20	6·35	9·37
DABINET	A	161	1·0563	13·06	·105	4·21	·27	4·80	7·62
	B	162	1·0560	13·40	·091	4·25	·27	4·50	7·25
	C	157	1·0570	13·00	·091	4·23	·28	5·68	8·53
	D	155	1·0545	12·98	·089	4·28	·27	6·25	10·25
	E	166	1·0560	13·19	·090	4·31	·27	5·80	7·68
	Crab	159	1·0552	13·00	·094	4·24	·27	5·44	8·83
	M 1	160	1·0567	13·22	·094	4·25	·28	5·28	7·83
Standard Error of Single Determinations		3·7	0·0024	0·41	·018	—	·02	—	0·68

Rate of fermentation was omitted from statistical consideration since it is an arbitrary measurement and is related to the total nitrogen content of the juice which can be more accurately determined. Similarly, the pH values of the juices were not treated statistically since pH is a function of the total acidity and the ash content; it was not practicable to determine the ash contents of these juices.

The statistical analysis of the results, presented below, is arranged in the general form of :—

1. Main Effects, (a) Variety, (b) Treatment, (c) Rootstock.

2. Two-Factor Interactions, (a) Variety x Treatment, (b) Variety x Rootstock, (c) Treatment x Rootstock.

The data are necessarily presented in the form of tables and the significant differences are briefly indicated. A more detailed consideration of these differences is deferred to a later section (Discussion).

RESULTS.

The comparison of yields of juice obtained from the samples of fruit is considered first, since it is distinct from all the other factors which are concerned with the composition of the juice. The order of presentation of these other factors is based on the importance of the correlations which they exhibit.

Yield of Juice.

Main Effects.

(a) *Variety.* Table II gives the mean yields of juice obtained from fruit of the three varieties; each figure is the mean of 16 samples (4 treatments x 2 rootstocks x 2 blocks.)

TABLE II.

Variety	Mean Yield of Juice (gallons/ton)	Difference required for significance
Stoke Red	176·7	($P = 0{\cdot}05$) 2·66
Sweet Alford	158·4	($P = 0{\cdot}001$) 4·77
Dabinett	159·1	

Stoke Red gives a significantly higher yield of juice (at the 0·1% level of probability) than either Sweet Alford or Dabinett, which between themselves show no significant difference.

(b) *Treatments.* The effects of rootstock and plot treatment on the yield of juice showed no significant differences.

Total Nitrogen.

Main Effects.

(a) *Variety.* Table III gives the mean nitrogen content of the juices of the three varieties; each figure is the mean of 16 samples (4 treatments x 2 rootstocks x 2 blocks).

TABLE III.

Variety	Total Nitrogen (mg./100 ml.)	Difference required for significance ($P = 0{\cdot}001$) = 0·88 mg./100 ml.
Stoke Red	3·00	
Sweet Alford	10·92	
Dabinett	8·41	

Differences between varieties are all highly significant (at the 0·1% level of probability) as would be expected. The values for Sweet Alford and Dabinett are more or less normal for cider varieties, but the value for Stoke Red is very low.

(b) *Treatments.* Table IV gives the mean nitrogen content of the juices for each of the four treatments; each value is the mean of 12 samples (3 varieties x 2 rootstocks x 2 blocks).

TABLE IV.

Treatment	Total Nitrogen (mg./100 ml.)	Difference required for Significance
A. Perennial Rye Grass	7·06	
B. White Clover (S.100)	7·18	($P = 0{\cdot}05$) 0·58 mg./100 ml.
C. Annual Cover Crop	6·90	($P = 0{\cdot}001$) 1·06 ,,
D. Clean Cultivation	8·64	

Differences between A, B, and C are not significant but treatment D gives a significantly higher nitrogen content even at the 0·1% level of probability.

(c) *Rootstocks.* Table V shows the mean nitrogen content of 24 juice samples from each of the two rootstocks (3 varieties x 4 treatments x 2 blocks).

TABLE V.

Rootstock	Total Nitrogen (mg./100 ml.)	Difference required for Significance ($P = 0{\cdot}001$) = 0·65 mg./100 ml.
Malling I	6·99	
Seedling Crab	7·90	

The Crab rootstock gives a higher nitrogen content which is significant at the 0·1% level of probability.

Two-Factor Interactions.

(a) *Interaction of Variety and Treatment.* Table VI shows how the total nitrogen contents of the juices of the three varieties are affected individually by the different cover-crop treatments. Each figure is the mean of four samples (2 rootstocks x 2 blocks).

The significant differences and their appropriate levels of probability are indicated in the table.

TABLE VI.

Variety	Total Nitrogen (mg./100 ml.) for Treatments :—				Probability			No Significant Difference
	A	B	C	D	$P = 0{\cdot}05$	$P = 0{\cdot}01$	$P = 0{\cdot}001$	
Stoke Red	2·77	3·13	2·80	3·30	—	—	—	A, B, C, D,
Sweet Alford	10·79	11·17	9·37	12·36	A>C D>A, B	B>C	D>C	A, B
Dabinett	7·62	7·25	8·54	10·25	C>B D>C	D>A	D>B	A, B
Difference Required for Significance					1·19	1·80	2·89	

(b) *Interaction of Variety and Rootstock.* Table VII shows the effect of rootstock on the total nitrogen content of the juices of the three varieties separately. Each figure is the mean of eight samples (4 treatments x 2 blocks).

TABLE VII.

Varieties	Total Nitrogen (mg./100 ml.) for Rootstocks :—	
	M.1	Crab
Stoke Red	2·79	3·22
Sweet Alford	10·22	11·63
Dabinett	7·97	8·86

The differences due to rootstock are not significant for any of the three varieties, though for Sweet Alford and Dabinett there is a tendency (significant only at P = 0·20) for the fruit from the crab rootstock to yield juices with a slightly higher nitrogen content. Nevertheless when all three varieties are combined (in Table IV) the differences are found to be significant at the 0·1% level; this is because a larger number of samples is available for statistical treatment.

(c) *Interaction of Treatment and Rootstock.* Table VIII shows the effect of treatment on the total nitrogen content of juices derived from fruit grown on the two rootstocks; each figure is the mean of six samples (3 varieties x 2 blocks).

TABLE VIII.

Rootstock	Total Nitrogen (mg./100 ml.) for Treatments :—			
	A	B	C	D
M.1	6·83	6·36	6·34	8·44
Crab	7·29	8·01	7·47	8·84

Differences between the nitrogen contents on M.1 and Crab are not significant at the 5% level ; under treatment B (White Clover) the figure for Crab tends to be higher, but the difference reaches significance only at the 20% level.

Total Acidity.

Of the three varieties, two are of low acidity (Sweet Alford and Dabinett) and one is of medium to high acidity (Stoke Red). The results are expressed as percentages of malic acid in the juice (g./100 ml.).

Main Effects.

(a) *Varieties.* Table IX shows the mean total acidities of the juices of the three varieties ; each figure is the mean of 16 samples (4 treatments x 2 rootstocks x 2 blocks).

TABLE IX.

Variety	Malic acid (g./100 ml.)	Difference required for
Stoke Red	0·629	significance (P = 0·001)
Sweet Alford	0·172	= 0·070
Dabinett	0·094	

The differences are all highly significant, as would be expected, and the only comment is that the figure for Dabinett is remarkably low even for a bittersweet variety.

(b) *Treatments.* Table X shows the mean total acidity of the juices for the four treatments ; each figure is the mean of 12 samples (3 varieties x 2 rootstocks x 2 blocks).

TABLE X.

Treatment	Malic acid (g./100 ml.)	Difference required for Significance	
A. Perennial Rye Grass	0·316	(P = 0·05)	0·015
B. White Clover (S.100)	0·301	(P = 0·01)	0·021
C. Annual Cover Crop	0·297	(P = 0·001)	0·028
D. Clean Cultivation	0·280		

Summarising these differences : at P = 5%, A > B = C > D : at P = 1%, B > D : at P = 0·1%, A > D. B and C are not significantly different.

(c) *Rootstock.* There was no significant difference between the mean total acidity of juices from the M.I. rootstock compared with that of juices from the crab rootstock.

Two-Factor Interactions.

(a) *Interaction of Variety and Treatment.* Table XI shows the mean total acidities of juices of the three separate varieties under the four cover-crop treatments ; each figure is the mean of four samples (2 rootstocks x 2 blocks).

TABLE XI.

Variety	Malic acid (g./100 ml.) for Treatments :—				Probability		No Significant Difference
	A	B	C	D	$P = 0{\cdot}01$	$P = 0{\cdot}001$	
Stoke Red	0·632	0·626	0·661	0·595		A>B B>D C>A, B, D	A, B
Sweet Alford	0·210	0·185	0·137	0·155		A>B, C, D B>C, D D>C	—
Dabinett	0·105	0·091	0·091	0·089	A>B, C, D	—	B, C, D
Difference required for Significance					0·013	0·017	

(b) *Interaction of Variety and Rootstock.*

(c) *Interaction of Treatment and Rootstock.* No significant differences were found in either of these two interactions.

" Tannin."

Very few differences of significance, between the factors concerned, were found when considering the " tannin " content of the juices.

Main Effects.

(a) *Variety.* Table XII shows the mean " tannin " content of the juices of the three varieties ; each figure is the mean of 16 samples (4 treatments x 2 rootstocks x 2 blocks).

TABLE XII.

Variety	" Tannin " (g./100 ml.)	Difference required for significance ($P = 0{\cdot}001$) = 0·03
Stoke Red	0·36	
Sweet Alford	0·21	
Dabinett	0·27	

The differences between varieties are, as would be expected, highly significant; the figure for Dabinett is abnormally low, while those for Sweet Alford and Stoke Red are surprisingly high compared with the normal "tannin" content of these varieties.

The effects of (b) *Treatment* and of (c) *Rootstock* on the "tannin" content of the resulting juices were not significant.

Two-Factor Interactions.

Only one interaction (*Variety and Rootstock*) revealed differences with a tendency to significance. These results are presented in Table XIII; each figure is the mean of eight samples (4 treatments x 2 blocks).

TABLE XIII.

Variety	"Tannin" (g./100 ml.) for Rootstocks:—	
	M.1	Crab
Stoke Red	0·37	0·35
Sweet Alford	0·20	0·21
Dabinett	0·28	0·26

These differences are not significant, but in the varieties Stoke Red and Dabinett there is a tendency (significant only at $P = 0{\cdot}20$) for the "tannin" content of juices from the M.1 rootstock to be higher than that of juices from the crab rootstock.

Specific Gravity.

Table XIV shows the mean values of the specific gravity of the juices of the three varieties; each figure is the mean of sixteen samples (4 treatments x 2 rootstocks x 2 blocks).

TABLE XIV.

Variety	Specific Gravity	Difference required for Significance ($P = 0{\cdot}001$) = 0·0031
Stoke Red	1·0474	
Sweet Alford	1·0652	
Dabinett	1·0559	

Differences in specific gravity between the varieties are highly significant. No other differences of significance were obtained; the variations caused by treatment, rootstock, first order interactions and error (higher order interactions) were all very small.

Total Sugars.

Table XV shows the mean total sugar content of juices of the three varieties; each figure is the mean of sixteen samples (4 treatments x 2 rootstocks x 2 blocks).

TABLE XV.

Variety	Total Sugars as "Invert Sugar" (g./100 ml.)	Difference required for Significance ($P = 0{\cdot}001$) = 0·55
Stoke Red	10·65	
Sweet Alford	14·72	
Dabinett	13·05	

Differences between varieties in the mean sugar content of the juices are again highly significant. As was observed with specific gravity, the variations due to other factors (treatment, rootstock etc.) were very small.

DISCUSSION.

In this paper an investigation has been made of the influence of cover-crop treatment and rootstock on certain properties and chemical constituents of the juices obtained from apples, of three varieties, grown on bush-trees.

From the statistical analysis of the data for these juices, it is seen that the effect of variety is dominant throughout and is the only factor causing significant variations in the following properties: yield, specific gravity, sugar content and "tannin" content of the juices. When considering the total acidity of the juices, however, the variations due to treatments and the interaction of variety and treatment are also found to be significant. While the total nitrogen content of a juice was largely determined by the variety, it was also affected significantly by both treatment and rootstock and to a variable extent by the interactions of variety and treatment.

Yield. The accuracy of the method employed to determine the yield of juice obtained from a known weight of fruit was limited by the apparatus available and by the difficulty of standardising the pressing procedure. The results are, however, of value since they are of the same order as those encountered on the larger commercial scale and the difference required for significance is not large (approximately 3 galls./ton at the 5% level of probability).

The variety Stoke Red gave a 10% higher yield of juice than was obtained from either Sweet Alford or Dabinett, which between themselves did not differ significantly in yield (Table II). This greater yield obtained from Stoke Red was however, associated with a lower sugar content in the juice (Table XV). The effects of treatment and rootstock on the yield of juice were not significant.

Total Nitrogen. Differences between the mean total nitrogen content of juices of the three varieties were all highly significant (Table III). This indicates that the nitrogen content is largely determined by the genetical make-up of the variety and suggests the interesting possibility of classifying varieties of cider apples according to the characteristic nitrogen contents of their juices. Such a classification would be useful in selecting varieties for ease of fermentation control; it would, however, be subject to variations due to physiological and nutritive factors in the environment of the tree, as is demonstrated by the results obtained here for variations due to treatment and rootstock.

Clean cultivation (Treatment D) yielded juices with significantly higher nitrogen contents than any of the cover-crop treatments; it is the usual

practice to grow cider fruit under grass, which would correspond most nearly to treatment A (Perennial Rye Grass).

The crab rootstock yielded juices with an average nitrogen content 13% higher than juices from the Malling I rootstock (Table V). No constituents of the juice other than nitrogen, have shown significant differences due to rootstock.

When the effect of cover-crop on the nitrogen content of the juices of the individual varieties is examined (Table VI), no significant differences are found for Stoke Red, owing to the very low levels of nitrogen present in the juices of this variety. For the other varieties, treatments A and B (Perennial Rye Grass and White Clover respectively) appear to be identical in their effect on the nitrogen content of the juice, while treatment D (Clean Cultivation) gives the highest values for this constituent. Further investigation is required to distinguish between the effects of treatments A, B and C.

The differences observed in the interactions of rootstock with variety and with treatment showed little or no significance, and require no comment.

Total Acidity. The acidity of an apple juice is largely determined by the genetical character of the variety and, in practice, the acidity of the juice is one of the factors used in the classification of varieties of cider apples. The data presented in Table X however, show that the effect of a cover-crop on the acidity of the juice obtained from the fruit is significant. Fruit grown under clean-cultivation yielded juices with reduced acidity and contrasted with that grown under Perennial Rye grass which yielded comparatively high acid juices.

" *Tannin* ". The " tannin " contents of these juices were found to be almost entirely determined by the variety and were not influenced at all by the nature of the cover-crop treatment. It was observed, however, when considering the effect of the two rootstocks on the individual varieties (Table XIII), that there was a tendency (significant only at the 20% level of probability) for the Malling I rootstock to induce a higher " tannin " content in juices of the varieties Stoke Red and Dabinett. This difference between the rootstocks must be confirmed before any definite conclusions can be drawn.

Specific Gravity and Sugar Content. Since the specific gravity of an apple juice is largely due to its content of sugars, these two factors may conveniently be considered together. In spite of the low standard error of these determinations, the only significant differences obtained in this investigation were between varieties (Tables XIV and XV). This was rather unexpected since the specific gravity of a juice is by no means a constant feature for the variety but varies widely from one sample of fruit to another.

From the data in Tables II and XV it is possible, by multiplying the yield of juice (gallons per ton) by the percentage of sugar in the juice, to obtain a figure for the amount of sugar extracted from a ton of fruit.

Thus the yields of sugar for the three varieties are :—

Stoke Red	.. .. ..	188 lb.	per ton.
Sweet Alford	.. .. ..	233 „	„ „
Dabinett	.. .. ..	208 „	„ „

The variety Stoke Red, although giving the greatest yield of juice, is seen to be the least profitable in yield of sugar.

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SUMMARY.

1. An investigation has been made of the effect of cover-crop treatment and rootstock on the chemical composition of juices of three varieties of cider apple (Stoke Red, Sweet Alford and Dabinett) grown on bush trees.

2. The following properties and juice constituents have been considered statistically :—

(a) Total nitrogen.
(b) Total acidity.
(c) " Tannin ".
(d) Specific gravity.
(e) Total sugars.
(f) Yield of juice obtained from the fruit.

3. The varietal influence was found to be dominant throughout, but cover-crop treatment and/or rootstocks were found to exert a significant effect on the nitrogen content and total acidity of the juices. Thus :—

(a) Clean cultivation leads to a higher nitrogen content and lower acidity than the other treatments.
(b) The crab rootstock induces a higher nitrogen content than the Malling I rootstock.

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THE EFFECT OF ION-EXCHANGE TREATMENT ON THE STABILITY OF APPLE JUICE.*

By S. W. CHALLINOR, MARGARET E. KIESER and A. POLLARD.

Ion-exchange adsorbents have come into increasing use for the de-acidification of fruit juices and extracts (e.g., 1, 2, 3). In spite of the wide application of such methods in these and related fields, as summarised by Riches (4) and by Davies (5), the effect of such treatments on the liability of juices to fermentation has, to the best of our knowledge, received little or no attention.

In the course of experiments on the de-acidification of apple juice, a very considerable reduction in the concentration of certain cations and anions took place, as observed by other workers. It occurred to us that such treated juices would be less able to support the growth of micro-organisms and there-

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Ion-Exchange Treatment and its Effect on Juice Composition.

Juice	Treatment De-Acidite D or Zeo-Karb Z	pH	Total Ash as % of Juice	Constituents as mg./100 ml. juice					
				Ca	Mg	Cu	Zn	P	N
1. Blenheim Orange	nil	3·62	0·274	14·2	7·0	0·21	0·64	12·4	14·0
2. ,, ,,	Z	2·30	0·048	trace	trace	0·03	0·07	12·2	7·0
3. Rival	nil	3·53	0·334	16·9	5·4	0·11	0·81	15·0	13·6
4. ,,	Z	2·23	0·049	trace	trace	0·03	0·15	—	—
5. ,,	Z, D, Z	2·33	0·003	,,	,,	0·02	0·07	1·2	1·2

fore less liable to undergo fermentation. If this were so, it would be of considerable practical importance. In this connexion, Dr. A. K. Zweede of Wageningen had informed us that sugar-beet extracts after treatment with adsorbents showed an increased stability. In our preliminary experiments it was found that apple juices given ion-exchange treatments and then freely exposed to air, showed much less fermentation than juices not so treated.

In more comprehensive tests, samples of depectinised and pulp-filtered apple juices were passed through laboratory columns of the Permutit ion-exchangers De-Acidite B and Zeo-Karb H.1. Typical results are given in Table 1. A marked change in juice composition was produced by the removal of cations in the Zeo-Karb column, accompanied by a corresponding increase in hydrogen-ion concentration. One passage through this adsorbent reduced the total ash in the Blenheim Orange juice 1 to 17·5% and the ash in the Rival juice 3 to 14·7% of the original values. A second passage of the latter juice through the re-generated column, after an intermediate treatment with De-Acidite to reduce acidity, further diminished the ash to 1% of its original value. As these treatments produced a significant change in pH, all juices tested micro-biologically were first adjusted to their original pH by the addition of a solution of sodium hydroxide (analytical grade) in glass-distilled water.

In the initial microbiological tests pasteurised samples of these juices were separately inoculated as follows, (a) with a loopful of a pure wine-yeast culture (Herrliberg) grown for 24 hours at 25°C in malt extract, (b) with a loopful of a suspension of the same yeast in glass-distilled water, prepared from a 24-hour-old streak culture on malt extract agar and (c) with a loopful of a washed suspension of the mixed microflora obtained by centrifugation from the untreated juice (Rival 3) which had been kept at room temperature for a few days and was actively fermenting. Suspension (c) consisted mainly of yeasts, relatively few bacteria being present. Precautions were taken to avoid introducing appreciable quantities of ions either from glassware or from the inocula. Thus, the suspensions were prepared in glass-distilled water and used immediately. The inocula were large—more than 20,000 viable organisms in inocula (a) and (b) and more than twice that number in inoculum (c) for each 7 ml. of juice.

In the earliest experiments—on treated juices of Bramley's Seedling—in which inocula (a) and (b) only were used ,a marked reduction of the growth of yeasts was observed. These encouraging results were followed by experiments on juices which had received more thorough treatment (double passage through Zeo-Karb). Each juice sample was separately inoculated with inocula (a), (b) and (c) and incubated aerobically at 25°C. No growth of the Herrliberg yeast occurred in the treated juice even after two weeks incubation. With the mixed yeast inoculum (c) a small deposit formed, sufficient to impart a very slight haze to the juice after vigorous shaking. That only slight multiplication of the mixed yeasts had, in fact, occurred was confirmed by microscopic examination. Furthermore, the yeasts had not the normal healthy appearance of those growing in the untreated juice. These results were confirmed in a subsequent experiment.

The nature of the effects observed in the treated juices presents many interesting problems. We are here interested mainly in those micro-organisms able to cause fermentation, i.e., the yeasts and certain bacteria ; suppression of the growth of fungi, however, is also of interest. Information on the general nutritional requirements of micro-organisms is not very detailed, but it is known that, in addition to the *main* requirements of C, H, O and N, other

elements or groups are also required. Among these are the following: PO_4''', SO_4'', CO_3'', Cl', Na, K, Mg, Fe, Ca, Cu, also possibly Mn, Zn, Co and Mo. It must be remembered also that the *ratios* of the concentrations of certain ions as well as their absolute quantities may be of significance.

It has not yet been possible to investigate in detail the deficiencies in our treated juices, but in preliminary analyses the elements given first attention were N, P, Ca, Mg, Zn and Cu. The reduction in total N in the treated Rival juice (5), as shown in the Table, was not such as would alone be expected to explain the present findings. The ion-exchange treatments gave most significant reductions in the concentrations of total phosphorus, calcium and magnesium, the two latter being reduced to less than 1% of their original values in this juice. Copper and zinc were also considerably reduced, but to a less marked extent. Spectrographic analysis of the earlier juices, made possible by the courtesy of the International Smelting Corporation, Avonmouth, confirmed the presence of Ca, Mg, Cu and Zn in the treated and untreated juices. Traces of Mn were also present but Mo was not detected.

In a further series of microbiological tests the following salts (analytical grade) were added to the treated juice, either separately or in combination, in amounts comparable with those present originally: ammonium sulphate (N and SO_4''), ammonium phosphate (N and PO_4'''), magnesium sulphate and calcium chloride. The juices were inoculated with the microflora of the Rival juice (3) and incubated at 25°C. After a *short* period of incubation (3 days), appreciable growth appeared only in the juices containing both added N and P, there being no marked difference between that containing added N and P only and that receiving N, P, Mg and Ca; growth, however, was very considerably less than in the original untreated juice. After a further 3 days incubation there was a marked difference between the juice receiving the four nutrients and that receiving N and P only; in fact, the amount of growth in the former was then of the same order as in the untreated juice.

The microbiological tests have been carried out aerobically. It should be borne in mind that apple juice is normally stored under conditions of restricted oxygen supply: under such conditions, however, the effects of ion-exchange treatment on juice stability would be expected to be similar or even more marked. Some evidence that this is so has been obtained from an experiment under less aerobic conditions.

We have attempted to apply these findings by storing treated and untreated juices in the laboratory at ordinary temperatures. Although the juices were unpasteurised and no aseptic precautions were observed, the treated juice (Rival 5) showed no obvious fermentation during the period of observation (4 weeks); some slight mould growth, however, occurred. Juice which had been de-aerated and bottled under CO_2 showed even greater stability. The untreated juice (Rival 3) was rapidly fermenting within three days.

It is thus apparent that ion-exchange treatment of apple juice effects the removal or partial removal of nutrients necessary for the growth of micro-organisms. Juices so treated become very much less liable to microbiological spoilage. Further experiments on this and other aspects of the work are in progress. If ion-exchange treatment should prove practicable on a commercial scale, then the industrial production of apple juice—and possibly of other fruit juices—might be radically changed, both in processing procedure and subsequent storage. It is obvious also that the results here recorded open up far-reaching possibilities in connection with the preparation and stability of other types of fruit products, e.g. cider and perry.

We wish to thank the Permutit Co., Ltd., for samples of the adsorbents used in this work.

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DOMESTIC APPLE JUICE PRODUCTION. PROGRESS REPORT II.

By ALICE CRANG, DILYS JAMES and MARGARET STURDY.

In the earlier progress report on the production of apple juice on a domestic scale (1) it was noted that pressings from fresh apples gave less cloudy juices than pressings from stored apples. The following experiments were made to study the effect of maturity of the apple on the clarity, pectin content and acidity of the juice.

Experimental.

Varieties used. Allington Pippin and Bramley's Seedling apples were stored in boxes in a cool apple store after harvesting, and pressings of each variety made once a fortnight from September 23rd to December 12th, 1947.

Extraction. As in 1946/47 a small hand press (The Lumley Press) was used with a bag made from cider press cloth. The minced apple pulp was twice pressed, the cake being macerated with water between the pressings (2).

Clarification. In order to hasten the filtering process without the use of a depectinizing enzyme, which is in short supply at present, pressure above the filter was obtained by raising the main supply 6 feet as suggested by Tressler *et al* (3). An aspirator jar containing the juice was placed on top of a stand 6 feet above a wooden trough, the juice being delivered through a glass tube into a calico bag resting on stainless wire netting in the trough, and thence to a basin. If the juice was cloudy after such filtering, a proportion was mixed with filter aid in the aspirator jar and filtered as before.

Sterilization. Mould due to contamination from corks has occurred in the past, even when corks have been boiled under water; therefore, the procedure was altered in 1947. Some bottles with china stoppers on wire bails were available, and others with corks. The rubber washers and corks were immersed overnight in a solution of sulphurous acid using 2 Campden Tablets and $\frac{1}{4}$ teaspoon citric acid to $\frac{1}{2}$ pint water. These substances were used as they are readily obtainable in the home. The loss due to mould contamination was not so severe as in previous years, but there was still a 10% loss.

The bottles were filled to within $1\frac{1}{2}''$ of the top with cold juice, the corks inserted and tied down or china stoppers with rubber washers rested on, then placed in a deep pan on a false bottom, with cold water up to the level of the bottom of the corks. The temperature was raised to 165°F. and maintained at that level for 30 mins.—the bottles were then removed, the wire bails adjusted and the juice allowed to cool before storing.

Analysis. After storage of 2-4 months duplicate bottles of juice from each batch were analysed for acid and pectin contents, also pH, specific gravity and clarity. The acidity was determined using the bromo-phenol-blue/phenol red method for apple juice (4) and pectin by the calcium pectate method of Carré and Haynes (5).

Comparative clarity was determined with the Spekker absorptiometer using an orange filter Retina No. 607. The juices were all diluted with an equal quantity of water before testing.

When the Spekker was set 0 to 1 for distilled water, a juice of perfect clarity was expressed as 0. A juice which just gave total obscurity at 1 showed that a range of dilutions 19 in 20 to 1 in 20 corresponded with a straight line graph 1 to 0. Comparison with the eye on a number of varying juices gave the following scale.

0·0 —0·1	Clear juice.
0·1 —0·25	Faint haze.
0·25—0·35	Haze
0·35—0·45	Decided haze.
0·45—0·6	Cloud.
0·6 —0·8	Thick cloud.
0·8 —1·0	Very thick cloud.

This method gave a direct comparison of clarity between juices of different colour, where descriptions alone are apt to be vague and inaccurate.

Results. The following table shows the analysis of untreated juices of

TABLE I.

Pressing Date	Ca pectate, gm/100 ml. Juice	Scale reading	*p*H	Acidity as Malic, gm/100 ml. Juice	Specific Gravity
Allington Pippin					
September 23/24	0·006	0·005	3·08	0·72	1·049
October 9/10	0·009	0·04	3·08	0·72	1·047
October 20/21	0·044	0·32	3·37	0·61	1·041
November 6th	0·078	0·63	3·36	0·53	1·040
November 20/21	0·098	0·43	3·54	0·41	1·040
December 3rd	0·110	0·62	3·54	0·50	1·045
Bramley's Seedling					
October 3/4	0·010	0·10	2·88	1·34	1·042
October 14/15	0·021	0·16	2·98	1·14	1·043
*November 10/11	0·172	0·68	3·16	0·93	1·041
November 26th	0·210	0·77	3·20	0·94	1·043
December 12th	0·235	0·63	3·24	0·81	1·038

* Juice pressed on October 27th lost with mould.

the two varieties. The amount of soluble pectin increased with maturity of the apple, agreeing with the findings of Carré and Horne (6). The turbidity also showed a corresponding increase, and the pH and acidity decreased as would be expected due to the physiological changes of the apple. The specific gravity showed a slight tendency to decrease, but was more influenced by the time taken to filter, which increased evaporation of the juice.

TABLE II.

Variety	Pressing Date	Filter Aid	Calcium Pectate content gm/100 ml.		Clarity Scale Reading	
			Treated Juice	Untreated Juice	Treated Juice	Untreated Juice
Allington Pippin	6th Nov.	" High-Flow "	0·053		0·14	
do.	do.	" Speedex "	0·046		0·06	
do.	do.	None		0·078		0·63
do.	20th Nov.	" High Flow "	0·096		0·35	
do.	do.	None		0·098		0·43
do.	3rd. Dec.	None (filtered overnight)	0·050		0·02	
do.	do.	None		0·110		0·62
Bramley's Seedling	10th Nov.	" Speedex "	0·115		0·20	
do.	do.	" Speedex " (warm)	0·182		0·18	
do.	do.	None		0·172		0·68
do.	26th Nov.	" High Flow "	0·231		0·36	
do.	do.	None		0·210		0·77
do.	11th Dec.	" High Flow "	0·230		0·53	
do.	do.	" High Flow " (warm)	0·208		0·64	
do.	do.	None		0·235		0·63

As juices began to show more than a faint haze, (scale reading above 0·25) after October 15th for both varieties, some of the juices from subsequent pressings were treated with filtering agents. Two brands " High Flow " and " Speedex " were used, and warming the juice to 86°F. was also tried. The results are summarised in Table II.

The decrease in turbidity of the treated juice over the untreated juice was very marked ; but using the filter-aid warm instead of cold did not give such good results. This was apparently because filtration of the warm juice was speedier and left more pectin in one of the juices than in the untreated juice, although this was not borne out by the subsequent trial with the second filter-aid.

Although using the filter-aid gave very good results in the earlier juices, when the clarity of the later treated juices is considered, it will be seen that they still fell into the classes classified as " decidely hazy " and " cloudy " after November 20th. The exception was the untreated juice from Allington Pippin which was allowed to drip through the filterbag overnight very slowly—this juice showed auto-depectinising action and was very clear, but the apple flavour was poor.

Losses due to Mould.

Eighty bottles were stored in all and eight showed mould growth in some form. Four of these were from cork infection of the Penicillium type, the other four had moulds which clarified the juices in the bottles, but gave rise to a floating or suspended growth in the juice which had been noticed in previous years, but not identified as mould growth. This mould is of the Mucorales type.

No correlation between acidity or heating and mould growth can be made, as in nearly all cases only one bottle from a batch showed mould growth, with the exception of the juice pressed on November 27th when both untreated bottles were contaminated. The moulds were also evenly distributed during the whole of the three month's trial.

DISCUSSION.

From the housewives' point of view the best apple juice is made from freshly harvested apples ; if apples are stored and allowed to ripen, as in cider-making, a cloudy juice results which requires extensive treatment to clarify it, and the treatments available for home use are not always reliable (1). Filter-aids help in clarifying the juice, and in the speed of straining, but do not produce such a clear product as that obtained by earlier pressing. If any quantity of juice is to be made, the use of a small hand fruit press and straining under pressure is to be recommended. It is necessary to heat the juice in the bottles and great care must be taken to prevent spoilage by moulds. If the heating period is increased, or a higher temperature used, there is danger of too much loss of flavour. In a previous investigation (7) it was found that a temperature of 180°F. for 20 mins. did not entirely obviate losses from mould growth.

SUMMARY.

(1) A clear apple juice can be made using apples as soon as they are brought in from the orchard.

(2) The variations in composition of juices from two varieties of apples pressed between October and December have been studied showing the increase in turbidity of the juice with the maturity of the apple before pressing.

(3) The merits of filter-aids for clarifying cloudy juices are discussed.

(4) A method of comparing turbidity in various apple juices using the Spekker absorptiometer is described.

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THE EFFECT OF MANURIAL TREATMENT ON THE COMPOSITION OF BLACKCURRANTS.

PROGRESS REPORT.

By JOAN D. BRYAN and A. POLLARD.

The large scale processing of blackcurrants to give products rich in Vitamin C has drawn greater attention to the composition of the fruit and especially to its vitamin content. Consequently, in blackcurrant growing both yield and composition have to be taken into account if the greatest amount of ascorbic acid (Vitamin C) is to be obtained. It has been known for some considerable time that the choice of variety is of great importance and it appeared possible that ascorbic acid production would also be affected by manurial treatment. The laying down of a field experiment on the effect of organic manurial treatments on growth and yield provided an opportunity to examine their influence on fruit composition. Descriptions of the test plots and of the effects of the manurial treatments on growth and on yield are given in the Report for 1946 (1) and in this Report (2). The chief manurial effects were those due to differences in nitrogen level in the bush, the supplies of potassium and phosphorus being adequate in all treatments.

METHODS.

The varieties Mendip Cross and Cotswold Cross were grown under six manurial treatments in replicated plots and the crop of each variety was cleared over a period of 1-2 days. Two pound samples of fruit were drawn during the picking from each separate plot and material for analysis was taken from the two pound samples. Estimations of ascorbic acid were carried out on the day of picking or on the following day after storage in the refrigerator overnight. The estimations were carried out by electrometric titration with dichlorophenolindophenol. Analyses for sugar and for titratable acid were made later on samples preserved in alcohol.

RESULTS.

The analyses of the fruit of the two varieties in the seasons 1946 and 1947 are given in Tables I and II. Each figure for Mendip Cross is the mean of 5 estimations for the replicate manurial plots and each figure for Cotswold Cross the mean of 4 estimations. Ascorbic acid is given as mg. per 100 g., sugar as the percentage of invert sugar and titratable acid as ml. *N* acid per 100 g. fruit, all being expressed on a fresh weight basis.

TABLE I

ASCORBIC ACID, SUGAR AND TITRATABLE ACID IN VARIETY MENDIP CROSS

Constituent	Year	Treatment						Significant Difference P = 5%
		1 Stable Manure	2 Drained Sludge	3 Straw-Sludge Compost	4 Straw-Nitro Chalk Compost	5 N.P.	6 Nil	
Ascorbic Acid	1946	175·6	168·0	179·6	183·0	174·0	179·6	9·51
,, ,,	1947	167·4	165·0	174·2	171·0	165·0	178·0	18·42
Sugar (as invert)	1946	6·74	6.55	6·85	6·73	6·33	6·82	0·438
,, ,, ,,	1947	7·23	7·42	7·48	7·59	7·26	7·82	0·643
Titratable Acid	1946	42·4	42·5	42·0	41·3	42·2	40·6	1·84
,, ,,	1947	37·0	38·2	38·8	38·6	36·8	37·0	2·77

TABLE II.

ASCORBIC ACID, SUGAR AND TITRATABLE ACID IN VARIETY COTSWOLD CROSS

Constituent	Year	Treatment						Significant Difference P = 5%
		1 Stable Manure	2 Drained Sludge	3 Town Refuse Compost	4 Meat and Bone Meal	5 N.P.	6 Nil	
Ascorbic Acid	1946	167·2	160·7	160·7	163·7	159·2	169·7	14·91
,, ,,	1947	139·2	140·2	144·7	137·2	129·0	156·2	22·27
Sugar (as invert)	1946	6·89	6·48	6·58	6·63	6·62	7·02	0·612
,, ,, ,,	1947	7·99	7·25	7·29	7·49	7·66	8·01	0·598
Titratable Acid	1946	39·1	38·3	38·8	38·7	37·3	39·5	2·68
,, ,,	1947	31·1	31·1	31·0	31·7	31·8	31·7	1·32

Ascorbic acid.

Cotswold Cross. The figures for 1946 suggest that the highest ascorbic acid is found in the bushes with low N status (treatments 1 and 6), but the differences found are not sufficient to be statistically significant. In 1947, treatment 6 gave an ascorbic acid value significantly higher than treatment 5 (high N).

Mendip Cross. In 1946 the bushes on treatment 2 (having a high N status) gave a level of ascorbic acid significantly lower than those receiving treatments 3, 4 or 6. In 1947 the differences were not significant although plot 6 (K only) again gave a high figure.

Sugar.

Cotswold Cross. In 1946 the low N bushes on plots 1 and 6 gave the highest values but the differences were not sufficient for significance. In 1947 the fruit from these plots (1 and 6) gave sugar levels significantly higher than that from plots 2 and 3.

Mendip Cross. In 1946 sugar levels were significantly higher in bushes on plots 3 and 6 than in the high N bushes on plot 5, but in 1947 although sugar was still high in bushes on plot 6 (K only), the differences did not reach significance.

Titratable acid.

In Cotswold Cross there were no significant differences due to treatment in either year. In Mendip Cross in 1946 the acid in the fruit from plot 6 was significantly lower than in fruit from plot 1 (bushes with low N status) or plot 2 (bushes with high N status). In 1947 no significant differences appeared.

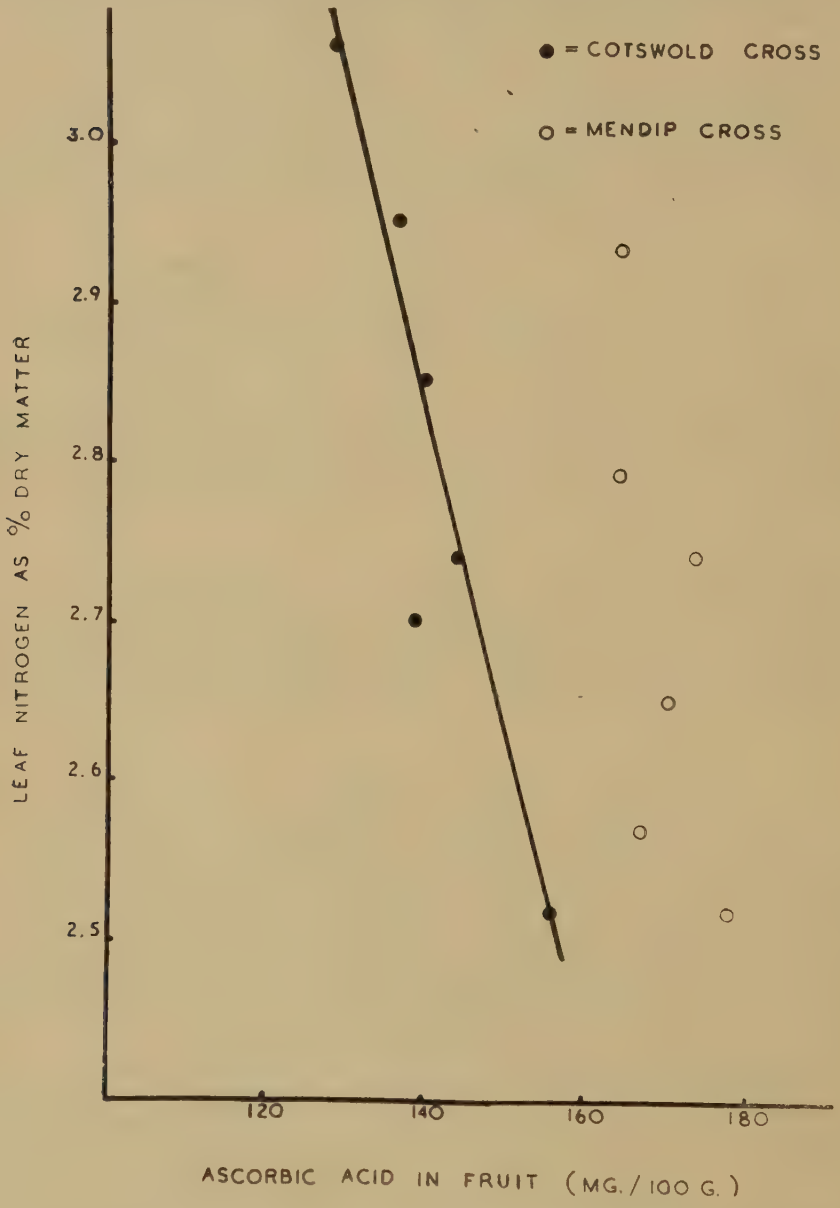
DISCUSSION.

The results indicate that differences in fruit composition are to be ascribed to the effects of manurial treatment on nitrogen status, ascorbic acid and sugar being highest in fruit from bushes with the lower levels of N. In this trial these were the bushes on plots receiving K only, stable manure or compost. The effects of nutritional status on the acidity of the fruit are inconclusive, possibly as a result of slight differences in the condition and degree of ripeness of the fruit. The difficulty of obtaining samples at the same stage of ripeness from a large number of plots simultaneously in a hot season is emphasised by the greater variation found in the 1947 analyses.

A comparison of the figures for fruit composition in the two years shows some considerable variations. In Mendip Cross there is little difference in ascorbic acid levels in the two seasons, but in Cotswold Cross the 1947 level is much lower than that in 1946. The sugar level is higher in 1947 in both varieties and the amount of acid is less. It would, however, be premature to ascribe these differences solely to seasonal effects, as variations in the degree of ripeness may also be concerned.

The chief effect of nutritional status on the fruit constituents studied has thus been the adverse effect of a high nitrogen level on ascorbic acid and sugar levels. The relation between ascorbic acid in the fruit and the nitrogen status of the bush is shown in the Graph in which leaf nitrogen in 1947 is plotted against ascorbic acid. The association of high leaf nitrogen with low ascorbic acid in the fruit is best shown by the figures for Cotswold Cross ; the figures

for Mendip Cross follow the same trend but the points show more scatter, for in this variety the differences were not statistically significant in 1947.



The effects of manurial treatment on growth vigour and yield are discussed fully elsewhere (1, 2) and it is clear that yield is very considerably increased by manures yielding ample supplies of available nitrogen. The lower ascorbic acid production at the higher nitrogen levels is thus more than offset by the increase in yield under these treatments. In Table III are shown the percentage ascorbic acid and yield in Cotswold Cross in 1947 for the plots 5 (bushes with high N) and 6 (bushes with low N). Although the amount of ascorbic

acid in the fruit is lower in bushes from plot 5, the production of ascorbic acid in pounds per acre is much greater.

TABLE III.

Plot	Ascorbic Acid %	Yield Tons/acre	Ascorbic Acid lb./acre
5 (bushes with high N)	0·129	3·70	10·7
6 (bushes with (low N)	0·156	2·36	8·3

SUMMARY.

A preliminary study has been made of the effect of organic manurial treatments on the composition of blackcurrants.

Estimations of ascorbic acid, sugar and titratable acid in two varieties have shown a relationship to exist between ascorbic acid and sugar levels and the nitrogen status of the bush. With increasing nitrogen uptake in the leaf the levels of ascorbic acid and sugar in the fruit are lowered.

An increase in the yield of fruit follows the uptake of nitrogen and this more than counterbalances the lower level of ascorbic acid. Thus the total production of ascorbic acid per acre is greatest with the higher nitrogen status of the bush.

ACKNOWLEDGMENT.

We wish to acknowledge the assistance of Miss M. Moseley in the analytical work.

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NOTES ON AN OVEN BOTTLING METHOD.

By ALICE CRANG, DILYS JAMES, and MARGARET STURDY.

Sterilizing bottles of fruit in an oven is often more convenient than using a deep pan of water. The method advocated has been to heat the bottles containing fruit, but no added liquid, in an oven at about 240°F. for ¾—1 hour for acid fruits, and 1½ hours for sub-acid ones such as pears or tomatoes. The jars are then removed from the oven, filled with boiling syrup or water, sealed and left to cool.

A variant of this method has been to fill the jars with fruit and liquid, and stand them in a shallow pan of water for heating in the oven. This has the advantage that there is less likelihood of the top fruit becoming scorched and the hot jars do not need the quick handling while the boiling liquid is poured on. In many cases, however, the times and temperatures used have not proved satisfactory so the following tests were made to remedy this.

EXPERIMENTAL.

The first series of tests was carried out in a domestic gas oven, using gooseberries and tomatoes as examples of acid and sub-acid fruits. The two-pound size of the screw-band type of glass preserving jars was used, with a maximum thermometer inserted in the centre fruit. The fruit was packed as tightly as possible without crushing and cold water or sugar syrup used to fill the jars. Some " solid pack " tomatoes were tested, in which the fruit was first blanched in boiling water, peeled and packed in halves or quarters so that the jars were filled without the addition of liquid. The rubber rings and lids were placed on the filled jars and the screw-bands adjusted loosely. The jars were placed in baking tins containing about one inch depth of water and heated in the oven.

Heating the gooseberries in this way for 45 minutes with oven temperatures at 240° or 280°F. was insufficient for sterilization. With an oven temperature of 270°F. the centre fruits attained a maximum temperature of 186° and 178°F. after 60 minutes when hot and cold water respectively was used in the baking tins. As acid fruits require to be held at 165°F. for several minutes, or else to reach 170°F., this processing would be sufficient in the pack used, but a longer cooking time would probably be required for fruits which pack more densely, such as blackcurrants.

The tomatoes, whether whole or " solid pack," had not reached the required sterilizing temperature of 190°F. after 90 minutes at 240° nor after 60 minutes at 310°F. The sterilizing times which are given for heating the bottles of fruit alone and filling with boiling liquid afterwards are therefore, insufficient for this method.

Further trials were made using an oil oven with a glass panelled door so that the rate of rise in temperature could be observed.

A hole was bored in the glass lid of a preserving jar, through which was inserted a thermometer held in place with rubber tubing, with the bulb in the centre fruit of the pack. The jar was filled either with fruit and cold syrup or water, or with " solid pack " apples or tomatoes which had been blanched in boiling water and cold dipped before packing in the jars. Various proportions of fruit and liquid were used. The jars were placed on baking tins with one inch depth of cold water, as before, and put on the same shelf as the oven thermometer. The oven temperature was kept as near 300°F. as possible. Other tests were carried out in the same way but using two-pound jam jars, in case there should be any appreciable variation in the rate of heat penetration. Twenty jars were heated in this way and graphs plotted of the rise in temperature during heating. The results are summarised in Table I.

The variation in the time taken to reach the required temperature for any one fruit is due to the different densities of the packs and also due to slight variations in the mean oven temperatures. The range in oven temperature was ± 20°, so the average temperature throughout the time of the experiment is given.

A typical heat penetration curve for a bottle of fruit, is shown on pp. 224. It will be noticed that the rate of heat penetration is greater between 100° and 170° than between 170° and 190°F. with the oven temperature at 300°F.

CONCLUSION.

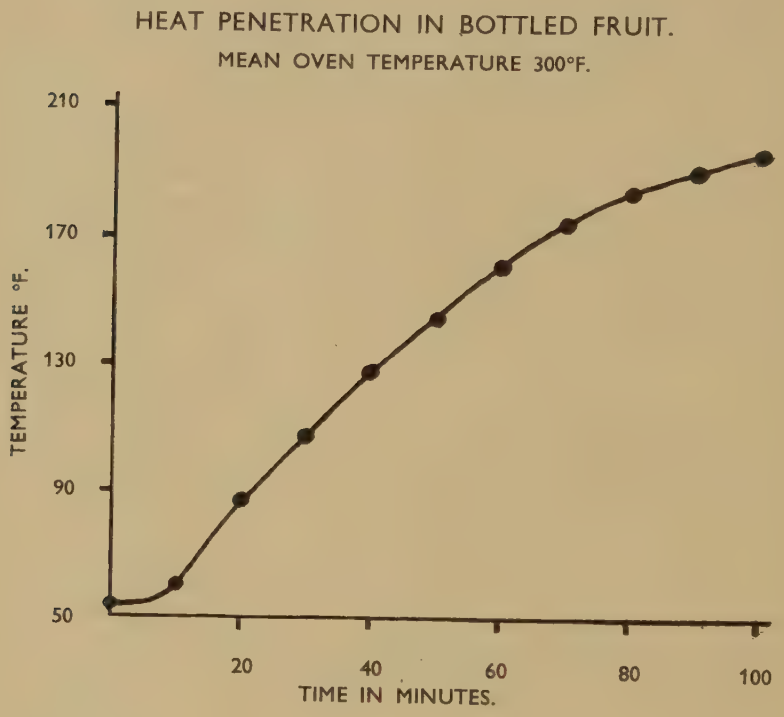
Since few housewives pack their jars to a known weight of fruit and all methods of heating are liable to fluctuations of temperature, due to variations

TABLE I.

Kind of Fruit	Weight or pack of fruit	Liquid	Required Fruit Temperature °F.	Time taken to reach Temperature. minutes	Mean Oven Temperature °F.
Whole Tomatoes	10 oz.	8 fl. oz. brine	190	85	303
,, ,,	10 oz.	,, ,,	190	85	303
,, ,,	10 oz.	,, ,,	190	95	< 300
,, ,, *	15 oz.	10 fl. oz. brine	190	80	299
,, ,,	10 oz.	8 fl. oz. brine	190	100	< 300
,, ,,	10 oz.	,, ,,	190	115	< 280
Skinned Tomatoes	Solid pack 16 oz.	No liquid	190	80	303
,, ,,	,, ,,	,, ,,	190	95	304
,, ,, *	Solid pack 22 oz.	,, ,,	190	100	297
Pears	Halved loose	10 fl. oz. 40° Brix syrup	190	80	300
,,	,,	,,	190	80	300
,,	Halved, tight	8 fl. oz. 40° Brix syrup	190	85	300
Sweet Cherries	13½ oz.	5 fl. oz. 40° Brix	190	60	302
Blackcurrants	Average Pack	Water	170	45	291
Redcurrants	9 oz.	8½ fl. oz. syrup	170	52	303
,,	12 oz.	5 fl. oz. syrup	170	70	308
,,	16 oz.	2 fl. oz. syrup	170	73	301
Apples in slices	9 oz.	6 fl. oz. 15° Brix syrup	170	56	303
,, ,,	10 oz.	5 fl. oz. 15° Brix syrup	170	70	298
Solid Pack Apples		no liquid	170	65	301

* Fruit packed in 2 lb. jam jar.

in load, a margin of safety is necessary over the average times required in these experiments. It is therefore suggested that the times employed for this method of sterilizing should be 75 minutes for acid fruits such as most of the larger berry fruits, stone fruits and cooking apples, 80 minutes for small berry fruits and sweet cherries, and 95 minutes for the sub-acid fruits such



as pears and tomatoes. During the cooking time the oven temperature should average at least 300°F. and not vary more than 20°. If higher temperatures are used, the sterilization should be satisfactory but the fruit may be overcooked.

It is most important that the screw-band types of jars should be screwed down tightly when the jars are taken from the oven and not before heating.

SUMMARY.

The method of filling jars of fruit with the liquid before sterilizing in the oven has been investigated, and the temperature of the oven, and the time required for cooking has been determined.

If the oven is maintained at a constant temperature of 300°F. most acid fruits should be cooked for 75 minutes, small berry fruits and sweet cherries for 80 minutes, and pears and tomatoes for 95 minutes. If the oven temperature were less than 300°F., considerably longer time would be required.

A COMPARISON OF THE PRESERVING QUALITIES OF CERTAIN VARIETIES OF RHUBARB.

By ALICE CRANG, D. P. JAMES, and M. STURDY.

Several varieties of rhubarb were grown to compare their relative cropping and preserving qualities and to determine the best season for preserving them. Each variety was tested in the spring and summer of the seasons 1946 and 1947.

EXPERIMENTAL.

Three aspects of the subject were investigated, namely :

A. The growth of the different varieties.
B. The chemical analyses of the petioles in the spring and summer of each year.
C. The bottling and jam-making qualities of the varieties tested in the spring and summer.

A. *Growth and Cropping.*

The eight selected varieties were grown together in the open without protection. The appearance of the plants in the spring was as follows :—

Variety	*Growth*
Champagne ..	Small plants with thin green and pink petioles.
Early Albert ..	Large plants with medium size petioles, pink or red in colour.
Linnæus	Long, thin to medium size petioles, green-red colour.
*Pershore	Small plants, thin to medium size petioles.
Royal Albert ..	Thick petioles, pink on the outside and green inside.
The Sutton ..	Long, medium to thick petioles, pink throughout.
Timperley Early ..	Small plants with dull red, thin to medium size petioles.
Victoria	Plants killed by frost.

* A local grower's variety in the Pershore area.

Timperley Early was the earliest of these varieties each spring, the first rhubarb being pulled from these plants on 3rd April, 1946 (a late spring), whereas Champagne was not ready until the following week, and the other varieties three weeks later.

Victoria proved too susceptible to frost damage for growing in the open without protection, as only one or two crowns survived the first winter and the yield from these was too poor for pulling. These plants succumbed to frost the following winter.

The average weight of a stem from the different varieties pulled in the spring is given on pp. 226. No figures are available for Pershore.

Throughout the summer, Champagne, Linnæus, Pershore and Timperley Early had tender leaf stems averaging 1 inch in width, whereas Early Albert, Royal Albert and The Sutton had thick stems.

Variety	Total Weight Petiole and Leaf	Prepared Weight	Leaves and other Waste
	(oz.)	(oz.)	(oz.)
Champagne	3·6	2·3	1·3
Timperley Early	6·0	3·2	2·8
Early Albert	8·1	5·1	3·0
Linnæus	9·3	4·7	4·6
Royal Albert	13·5	8·5	5·0
The Sutton	17·8	9·7	8·1

B. *Analysis.*

The analysis of the rhubarb petioles was carried out in the spring and summer in 1946 and 1947.

For analysis, representative samples of the thicker and thinner petioles were taken from each variety. As soon as possible after picking, the root ends and leaves were removed, and slices cut from the base, middle and leaf end of each petiole, using stainless knives. The slices were at once placed in weighed metaphosphoric acid solution for ascorbic acid analysis, while the remainder of the stem was finely cut up for the rest of the analysis.

The extracts prepared for the determination of ascorbic acid were tested for reductones (1), but none were found to be present.

In estimating the pectins, preliminary acetone precipitation was necessary before proceeding with the determinations using the method of Carré and Hayes (2), otherwise other substances were precipitated with the calcium pectate.

The " tannin " content tested in each variety was very small, averaging 0·03% in all the varieties tested in the spring and summer.

Rhubarb juice was tested for pH value from a thick and thin petiole from each variety in the spring and summer of 1946. Separate determinations were carried out from the root end, middle and leaf end of each petiole. In the spring rhubarb there was a slight decrease in pH value towards the leaf end, but this was too small to be significant. There was also no significant difference between the pH values of a thick and thin petiole of the same variety, nor between that grown in the spring and summer, in spite of a large increase in total titratable acidity in the summer rhubarb.

The detailed analysis of the different varieties is given in Table I. Each determination was carried out in duplicate. The acid is given as percentage of malic acid, as this has been found to be in the highest proportion (3).

The chief point of interest is the variation in the analysis of the spring and summer petioles. With each variety tested, the summer rhubarb contained considerably more of each ingredient tested, except cane sugar, than that pulled in the spring. In spite of very different climatic conditions during the two summers, 1946 being exceptionally wet and 1947 dry, the variation between the two years is generally very small.

The higher pectin and acid figures obtained in the summer would indicate that this is the time for making rhubarb into jams.

TABLE I.

Variety and Season	Total Solids %	Insoluble Solids %	Cane Sugar %	Reducing Sugar % (as invert)	Non-Sugar Solids %	Acid as Malic %	pH	Ascorbic Acid mg/100g.	Pectin as Calcium pectate %
Champagne									
Spring 1946	4·83	1·86	0·18	0·74	3·91	1·22	3·15	13·2	0·48
,, 1947	4·00	1·48	0·09	0·33	3·58	1·58	—	9·1	0·36
Summer 1946	7·90	—	0·06	1·29	6·55	1·74	3·17	20·7	0·52
,, 1947	7·34	2·92	0·00	1·20	6·14	1·57	—	16·0	0·54
Average	6·02	2·09	0·08	0·89	5·05	1·53	3·16	14·7	0·47
Early Albert									
Spring 1946	5·26	1·67	0·00	0·95	4·31	1·49	3·05	13·4	0·26
,, 1947	4·70	2·02	0·04	0·52	4·14	1·62	—	15·7	0·30
Summer 1946	7·00	—	0·16	1·16	5·68	1·96	3·22	11·6	0·77
,, 1947	8·01	2·53	0·00	1·48	6·53	1·66	—	23·1	0·47
Average	6·24	2·07	0·05	1·03	5·16	1·69	3·13	15·9	0·45
Linnaeus									
Spring 1946	4·73	1·59	0·00	0·83	3·90	1·44	3·10	8·6	0·28
,, 1947	4·49	1·24	0·13	0·50	3·86	1·33	—	7·4	0·24
Summer 1946	6·89	—	0·29	1·77	4·83	2·07	3·16	14·6	0·45
,, 1947	8·48	2·67	0·00	1·24	7·24	1·86	—	11·5	0·67
Average	6·15	1·83	0·10	1·08	4·96	1·68	3·13	10·5	0·41

TABLE I—(*contd.*)

Variety and Season	Total Solids %	Insoluble Solids %	Cane Sugar %	Reducing Sugar % (as invert)	Non-Sugar Solids %	Acid as Malic %	pH	Ascorbic Acid mg/100g.	Pectin as Calcium pectate %
Pershore									
Spring 1946	4·52	1·71	0·00	0·79	3·73	1·35	3·01	8·3	0·22
,, 1947	3·94	1·35	0·00	0·30	3·64	1·50	—	6·8	0·23
Summer 1946	7·79	—	0·09	1·76	5·94	2·07	3·55	16·4	0·58
,, 1947	7·85	3·55	0·00	1·54	6·31	1·72	—	21·2	0·61
Average	6·02	2·20	0·02	1·10	4·90	1·66	3·28	13·2	0·41
Royal Albert									
Spring 1946	5·02	2·70	0·05	0·90	4·07	0·73	3·47	10·4	0·27
,, 1947	5·30	2·09	0·00	0·40	4·90	1·34	—	9·6	0·43
Summer 1946	8·81	—	0·03	1·76	7·02	1·57	3·59	24·8	—
,, 1947	7·15	2·79	0·00	1·63	5·52	1·72	—	13·6	0·64
Average	6·57	2·53	0·02	1·17	5·38	1·34	3·53	14·6	0·45
The Sutton									
Spring 1946	5·15	—	0·05	0·97	4·13	0·94	3·15	11·4	0·11
,, 1947	4·87	1·65	0·00	0·56	4·31	1·57	—	16·4	0·35
Summer 1946	—	—	0·03	1·34	—	2·15	3·09	30·3	0·62
,, 1947	7·50	2·30	0·00	1·59	5·91	2·03	—	21·4	0·62
Average	5·84	1·97	0·02	1·11	4·78	1·67	3·12	19·9	0·42

TABLE I—(*contd.*)

Variety and Season	Total Solids %	Insoluble Solids %	Cane Sugar %	Reducing Sugar % (as invert)	Non-Sugar Solids %	Acid as Malic %	pH	Ascorbic Acid mg/100g.	Pectin as Calcium pectate %
Timperley Early									
Spring 1946	4·09	1·46	0·16	0·72	3·21	1·02	3·29	12·0	0·42
,, 1947	4·44	1·34	0·20	0·34	3·90	1·58	—	9·0	0·21
Summer 1946	7·31	—	0·01	1·50	5·80	1·87	3·25	14·0	0·38
,, 1947	7·15	2·29	0·00	1·61	5·54	2·12	—	12·1	0·24
Average	5·74	1·70	0·09	1·04	4·61	1·65	3·27	11·8	0·31
Average Results									
Spring 1946	4·80	1·83	0·06	0·84	3·90	1·17	3·17	11·0	0·29
,, 1947	4·53	1·60	0·07	0·42	4·04	1·50	—	10·6	0·30
Summer 1946	7·61	—	0·10	1·51	5·97	1·92	3·29	18·9	0·55
,, 1947	7·64	2·72	nil	1·47	6·17	1·81	—	17·1	0·54

The ascorbic acid (vitamin C) content of several of the varieties tested was higher than anticipated. For instance the variety " The Sutton " with an average value of 26 mg. per 100 g. in the summer compares favourably with many fruits. Allowing for about one quarter being lost in cooking, this would still contain an appreciable amount of ascorbic acid provided that there was no undue delay between pulling and cooking the rhubarb.

C. *Preserving qualities.*

The bottling and jam-making qualities of these rhubarb varieties were tested in the spring and summer.

I. Bottling.

Freshly pulled rhubarb was prepared by cutting into one inch lengths and packing into 1 lb. glass covered preserving jars. Each jar was packed as tightly as possible. The jars were then filled with cool 30° Brix sugar syrup, covered and processed by immersing the jars in cold water, raising this to 165°F. in 1½ hours and maintaining at that temperature for 10 minutes. In this way the rhubarb was sufficiently sweetened for tasting, and cooked without breakdown.

In 1946, the spring and summer rhubarbs were scored for colour and flavour by a panel of judges after about 2 months storage, but the following year both spring and summer rhubarbs were scored together during December, so that it was possible to compare the same variety pulled in the two seasons.

The results were as follows, the varieties being placed in order of merit.

Flavour :

Variety	1946		1947		General Remarks
	Spring	Summer	Spring	Summer	
Linnæus	1st (tied)	1st	4th	1st	Good
Champagne	1st (tied)	2nd	3rd	2nd (tied)	Good, mild
Pershore	3rd	3rd	1st	2nd (tied)	Quite good
Timperley Early	Fairly good	Fair, rather acid	2nd	Poor	

The other three varieties were considered to have rather a poor flavour. A point of interest noted in both years was that the Champagne rhubarb flavour deteriorated quickly after the bottle had been opened an hour or two; otherwise this variety would have been placed first.

When the spring and summer rhubarbs were tested together, the spring rhubarb was always far superior in flavour to the summer, in spite of longer storage which would tend to detract from this quality.

Colour: The ratings for colour were as follows:

Variety	1946		1947		General Remarks
	Spring	Summer	Spring	Summer	
Early Albert	2nd	1st	1st	4th	Spring: pink Summer: dull red
Champagne	1st	—	2nd	3rd	Spring: pink Summer: greenish- or dull red; pink juice.
Pershore	—	2nd	3rd	2nd	Greenish-pink each time.
Linnæus	—	3rd (tied)	—	1st	Green in spring more pink in summer

Of the other varieties, The Sutton was pale pink to dull red in the spring with red juice and green stems in the summer. Royal Albert was very pale pink to green in colour, and Timperley Early green or greenish pink.

The spring rhubarb tended to be more delicate in colour, being a pleasant pink or greenish colour, while the summer rhubarb tended to give dull red juice and green stems.

Texture: The outstanding points about the texture of the bottled rhubarb was that Champagne was considered the best and Royal Albert as very coarse. There was again a most striking difference between the spring and summer stems, the latter all tending to be very coarse and tough.

The general conclusions are that the spring rhubarb should be used for bottling while the petioles are young and tender. The variety Champagne was awarded the highest marks when colour, flavour and texture were considered together, with Linnæus second, and Pershore as third. Timperley Early, a variety said to produce brighter stems than most varieties in Yorkshire, was disappointing in this respect when bottled, whereas Early Albert was first in colour, but poor as regards flavour and texture.

II. Jam.

The jams were made from 3 lb. of prepared rhubarb, $2\frac{1}{4}$ lb. of sugar and $\frac{1}{4}$ pint of water, boiled to $3\frac{3}{4}$ lb. They were stored in semi-darkness.

Jam was made from the seven varieties in the spring and summer of 1946 and in the spring of 1947. They were scored at the same time as the bottled fruit for that season.

The jams were in each case set sufficiently not to pour readily, but the consistency was "sticky" rather than a true pectin gel. "The Sutton" gave a slightly firmer consistency than the other varieties.

Flavour: Linnæus was considered to make the best flavoured jam, being placed first in two of the series and second in the third. The Sutton was next, being placed first in one and second in another series, but scored lower when stored for eight months before testing. The order of preference for the other varieties was Pershore, Timperley Early, Early Albert, Royal Albert and Champagne last, being considered insipid.

Colour: The jam colours varied from pink, red-brown to green, and deteriorated during storage.

The Sutton and Champagne gave the best coloured jam, being pink when first made. This, however, deteriorated to a red-brown and red-green on keeping. Linnæus gave a green coloured product which was preferred by most to the dull red-brown or green-red colours of the other varieties. Early Albert gave a pink-brown coloured jam when first made but was very dull green-red on keeping.

CONCLUSION.

A. Of the rhubarb varieties grown, Victoria proved unsuitable for growing without protection and succumbed to frost.

Champagne, Pershore and Timperley Early remained small plants: Champagne particularly seemed to have less vigour than the other varieties. Linnæus had more vigour, with long, thin petioles. Early Albert, Royal Albert and The Sutton grew into vigorous plants but the petioles were very thick and tended to be coarse.

Timperley Early was the earliest variety each spring.

B. The rhubarb pulled in the spring was much lower in reducing sugars, acid, pectin, ascorbic acid and general solid matter than the same varieties pulled in the summer, but there was no great variation in the individual varieties when comparing the figures obtained in the spring or the summer of the two years under consideration.

The ascorbic acid content of some of the summer pulled rhubarb was higher than anticipated, the variety "The Sutton" being the best in this respect.

C. There was a marked difference in quality between the spring and summer bottled rhubarb, the former being greatly superior as regards flavour and texture, while the brighter colour was generally preferred. The variety Champagne was considered the best for bottling quality when colour, flavour and texture were considered, though, as its flavour seemed to deteriorate quickly, Linnæus was awarded more marks on flavour alone. The variety from Pershore was considered third and Timperley Early fourth in bottling quality.

The higher acid content of the summer rhubarb was very noticeable and more sugar was needed to make it palatable than with the spring rhubarb, and all varieties tended to be tough in the summer.

The higher pectin and acid contents of the summer petioles would make them more suitable for making into jam than the spring stems. The qualities of the jam made in the different seasons varied but the varieties Linnæus and The Sutton were generally first and second, while the flavour of Champagne was too weak and came last in the series. The colour of all the jams deteriorated on storage.

SUMMARY.

1. The growing and preserving qualities of eight varieties of rhubarb have been compared. One of these, Victoria, proved too susceptible to frost for growing without protection.

2. The analyses of the petioles of each variety pulled in the spring and summer of 1946 and 1947 are given, the summer rhubarb being considerably higher in solid matter including sugar, acid, pectin and ascorbic acid contents.

3. The spring pulled rhubarb was greatly superior in bottling quality to that grown in the summer, but the latter was more suitable for jam-making though the texture was "sticky." The varieties Champagne and Linnæus

were considered the best for bottling, and Linnæus or The Sutton for jam-making.

ACKNOWLEDGMENTS.

Our thanks are due to Mr. E. W. Hobbis for growing the rhubarb and to Miss M. Atherton and Miss E. Gilbert for assistance in the preserving and analytical work.

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FACTORS AFFECTING QUALITY IN POTATOES. IV.

By A. POLLARD, MARGARET E. KIESER, and ALICE CRANG.

Some of the factors influencing potato quality were studied in the years 1944, 1945 and 1946 and the results have been described in the Reports for those years (1, 2, 3). In the 1947 season further tests were made on potatoes from three of the sites used in the previous trials, at the Centres numbered I, II and V in 1946.

The effects of site, variety and manurial treatment on potato quality were again evident in the 1947 tests and the results are in agreement with the earlier findings. A rather wider range of varieties was used in 1947 and the effect of variety on potato quality has thus been brought out more noticeably, particularly in regard to blackening after boiling. A detailed account of the mineral status of the plants during the growing season is given elsewhere in this Report (4).

FIELD OBSERVATIONS.

Centre I. (Long Ashton, Plot 17a)

The soil and manurial treatments for this plot were described in detail in the Report for 1944 (p. 186). In 1947 the treatments were as described there except that nitrochalk was used as a source of nitrogen instead of sulphate of ammonia. Severe K deficiency was again evident in the no-manure and NP plots, while deficiencies of N and Mg were of medium severity where N was omitted from the fertiliser dressing.

Centre II. (Swaffham).

This centre was described in the Report for 1945 (p. 209) and was a light Black Fen peat. In 1945 potatoes received factorial dressings of N, P and K and the main deficiency noted was of K with slight effects of —P and —N. In 1946 the field carried a wheat crop and in 1947 it was again planted with potatoes, no fertilisers being added since the 1945 treatments. Thus the only fertiliser effect in 1947 was that due to the residues of the 1945 treatments. Some K deficiency was apparent during the growing season on the plots which had not received K dressings in 1945.

TABLE I.

LONG ASHTON PLOT 17A. MANURIAL TREATMENT. AVERAGE SCORES.

	Treatment	Red King				Kerr's Pink				Majestic			
		External Appearance	Texture	Flavour	Colour	External Appearance	Texture	Flavour	Colour	External Appearance	Texture	Flavour	Colour
No Magnesium Sulphate	Nil	3·0	3·5	3·7	4·0	3·0	3·0	4·2	4·2	2·7	3·5	3·2	2·7
	F.Y.M.	4·0	3·7	4·2	4·5	3·5	3·0	4·0	4·5	4·2	4·7	3·7	3·5
	N.P.K.	4·0	4·0	4·7	4·7	3·2	2·5	4·2	4·5	3·7	4·0	3·5	3·5
	P.K.	4·0	4·5	4·7	5·0	3·0	3·0	4·0	5·0	4·0	4·0	3·2	4·2
	N.K.	3·7	3·7	4·2	4·7	3·5	4·2	4·5	4·2	3·2	3·0	2·7	2·5
	N.P.	3·2	3·2	4·0	3·7	3·2	3·7	4·5	3·7	2·2	2·0	3·0	2·2
Magnesium Sulphate	Nil	2·5	2·5	3·0	3·5	4·0	4·0	5·0	4·0	2·5	4·0	3·0	3·0
	F.Y.M.	4·5	4·5	4·0	4·5	2·0	3·5	4·0	5·0	4·0	4·5	4·0	4·0
	N.P.K.	3·5	4·0	4·5	3·0	2·0	3·5	4·5	4·0	4·5	4·5	4·0	3·0
	P.K.	4·5	4·5	5·0	4·5	3·5	3·5	4·0	4·0	4·0	4·0	3·5	4·5
	N.K.	3·5	4·0	4·0	3·0	2·0	3·5	4·0	4·0	3·0	3·5	3·5	2·5
	N.P.	3·5	5·0	3·5	1·5	3·0	3·0	3·0	3·5	2·5	3·5	3·0	2·0

Centre V. (Sutton Park)

The site and fertiliser treatments at this centre were as described in the Reports for the previous three years (1944, p. 191, Centre C : 1945, p. 210, Centre V : 1946, p. 159, Centre V). The soil is reclaimed acid heath and has received a series of N, P and K treatments, both with and without the application of lime at the rate of 9 tons per acre. As in previous years, where no lime was given, symptoms of Ca deficiency and of Mn toxicity appeared, while Mg deficiency was also generally observed. When lime was applied, symptoms of —N, —P and —K appeared where these elements were not given and there was some evidence of a gradient of P across the plot as in 1945.

COOKING TESTS.

The potatoes were boiled as described previously and were awarded scores from 0 to 5 for External Appearance, Texture, Flavour and Colour (i.e. freedom from blackening).

Centre I. (Long Ashton).

Three varieties were grown at this centre, viz. Majestic, Red King and Kerr's Pink ; the scores for quality are given in Table I.

Majestic.

In the previous two years the samples had shown excessive breakage, but in 1947 they were the reverse and were too solid and insufficiently floury. The best samples were those which had received NPK, PK or farmyard manure dressings. These treatments also gave samples with the best colour. Blackening was severe in the no-manure, NK and NP plots with colour ratings 2 to 3 and was worst in the NP treatments. The addition of Mg to the fertiliser treatments gave a slight improvement in general quality but had no definite effect on blackening. All the Majestic samples had an excessively sweet taste which did not appear related to any fertiliser treatment.

Red King.

These samples were of better quality than the Majestic and showed much less blackening. Appearance and texture were also better but the samples ranged from excessive " soapiness " in the no-manure plots to rather too much breakage in the plots receiving farmyard manure or PK dressings. Blackening was only slight, even in the worst samples from the no-manure and NP plots, and in these the colour scores were between 3 and $3\frac{1}{2}$. The addition of Mg gave more variable samples and blackening was slightly more prevalent. The flavour of the samples was good.

Kerr's Pink.

These samples differed from Majestic and Red King in showing excessive breakage in all samples except those from the no-manure and NP plots, where the texture was more solid and starchy. The other samples all disintegrated on boiling so that the outer layers sloughed off before the centres were fully cooked. The outer layers also had the unpleasant gummy texture noted in the 1946 crop of this variety. The flavour of the samples was good and blackening was only appreciable in the samples from the NP plots where the colour scores were $3\frac{1}{2}$. The application of Mg was associated with even more breakage on boiling, the other characters being little affected.

Centre II. (Swaffham). Arran Consul.

The samples received only moderate scores for appearance, texture and flavour, usually from 2-4. They were all insufficiently floury and too solid in texture. Blackening was intense and the highest colour score given was $2\frac{1}{2}$. The average quality scores for the different levels of N, P and K (given in 1945)

TABLE II.

CENTRE II. SWAFFHAM. AVERAGE SCORES (1947 CROP). ARRAN CONSUL.

Treatment in 1945	External Appearance	Texture	Flavour	Colour
N_0	2·8	3·1	3·2	1·0
N_1	2·8	2·8	2·7	0·9
N_2	2·7	2·9	2·7	0·5
P_0	3·0	3·4	3·5	1·4
P_1	2·7	2·8	2·8	1·0
P_2	2·7	2·7	3·3	0·2
K_0	2·7	3·1	3·3	0·7
K_1	2·8	2·7	2·4	1·0
K_2	2·8	3·1	2·8	0·8

are shown in Table II. There appeared to be no residual effect of the K dressings on colour but a slight adverse effect of both N and P. Appearance and texture showed no definite effect of the previous manurial treatments but flavour appeared slightly better at the lowest N level.

Centre V. (Sutton Park).

The following six varieties were grown on this site : Kerr's Pink, Dunbar Rover, Arran Banner, King Edward, Gladstone and Majestic. Without lime all the varieties gave poor yields of small tubers, usually solid and immature in appearance. When lime was applied more normal yields were obtained as in the trials of previous years. A short description of the samples of each variety will be given followed by a description of the fertiliser effects as a whole.

Kerr's Pink.

This variety was of fairly good texture even without liming (average score 3·9) and the use of lime brought about little improvement in texture although the appearance of the samples was better. Blackening was fairly severe when K was withheld, but was slight or absent when K was included in the fertiliser treatment. Blackening was not consistently affected by liming.

Dunbar Rover.

Without lime the tubers were small and solid, but they were slightly better in texture when lime was given, the average value for texture being raised from 3·1 to 3·4. More improvement was produced in appearance, the score being raised from 2·8 to 3·6. Blackening was absent in the best samples before liming and was only severe in one no-manure plot. Following the use of lime, blackening was severe where K was not given.

Arran Banner.

Without lime the tubers were all of poor quality and were too solid in texture and shiny in appearance. Blackening was present in all treatments. Liming gave a slight improvement in appearance and texture and some improvement in flavour. Blackening was more intense following liming where K was not given, but blackening was reduced when both lime and K were given.

King Edward.

Without lime the samples were very poor in appearance and texture and rather poor in flavour. Blackening was general and diffuse in nature, no tubers being of good colour. Liming improved texture but the tubers were still insufficiently floury. Blackening was intensified where K was not given, but when both lime and K were given the colour was improved.

Gladstone.

The samples were solid in appearance but were not "soapy" and the scores for texture ranged from 2 to 4. Neither texture nor appearance was improved by liming. Blackening was moderate and greatest in the no-manure plots. Liming greatly intensified blackening and there was no definite response to K.

Majestic.

The quality was very poor both before and after liming, the samples being shiny in appearance and solid in texture. Blackening was very severe and was intensified by liming. Fertilisers containing K had no definite effect on colour.

All Varieties.

The effects of liming and of the fertiliser treatments are shown in Tables III and IV and the results may be summarised as follows :—

Liming improved external appearance, texture and flavour in all varieties except Gladstone.

When K was omitted from the fertiliser treatment liming gave a general increase in blackening in all varieties except Kerr's Pink. But when K was given the effect of lime differed according to the potato variety ; blackening was increased by liming in Dunbar Rover, Gladstone and Majestic, but was decreased in Arran Banner and King Edward. Kerr's Pink was less definitely affected.

When lime was not given fertiliser treatments had little effect, and blackening was not reduced by K treatments except in Kerr's Pink where a slight beneficial effect of K was apparent.

When lime was given the effect of K on blackening was seen in the four varieties Kerr's Pink, Dunbar Rover, Arran Banner and King Edward. In

all these, the samples from plots receiving K showed less blackening than those from plots not receiving K. Neither Gladstone nor Majestic gave any consistent response to K and blackening was severe in all samples.

TABLE III.

CENTRE V. SUTTON PARK. EFFECT OF LIMING ON QUALITY (AVERAGE SCORES FOR ALL FERTILISER TREATMENTS).

Variety	External Appearance		Texture		Flavour		Colour	
	No Lime	Lime	No Lime	Lime	No Lime	Lime	No Lime	Lime
Kerr's Pink	3·9	4·2	3·9	3·9	4·0	4·3	3·7	3·4
Dunbar Rover	2·8	3·6	3·1	3·4	3·6	4·0	3·8	2·1
Arran Banner	2·4	3·1	3·2	3·3	3·6	4·1	2·5	2·2
King Edward	1·6	2·8	2·2	3·4	3·5	4·2	3·2	3·4
Gladstone	2·4	2·3	3·2	2·6	3·9	3·3	3·6	2·1
Majestic	1·1	2·1	2·2	2·5	2·5	3·0	1·0	0·6

TABLE IV.

CENTRE V. SUTTON PARK. EFFECT OF FERTILISER TREATMENT ON COLOUR.

Treatment	Kerr's Pink		Dunbar Rover		Arran Banner		King Edward		Gladstone		Majestic	
	No Lime	Lime	No Lime	Lime	No Lime	Lime	No Lime	Lime	No Lime	Lime	No Lime	Lime
Nil	2·0	3·0	4·5	1·5	3·0	0·5	3·0	3·0	3·0	2·0	0·5	0·0
P	4·0	3·0	4·5	2·0	3·5	0·5	4·0	2·5	4·0	3·5	3·0	0·5
NP	2·5	3·0	5·0	0·0	2·5	1·0	3·5	2·5	3·5	0·5	1·0	2·0
K	4·0	4·5	4·5	3·5	3·0	4·5	3·5	4·0	3·5	1·0	0·5	0·0
NK	4·5	4·5	4·0	3·5	2·0	3·5	3·5	4·5	4·5	3·5	1·0	2·0
PK	5·0	4·0	3·0	3·0	2·5	4·0	3·5	4·0	4·0	3·5	1·0	0·5
NPK	4·5	3·5	3·5	2·5	2·0	3·5	2·5	4·0	3·5	2·0	0·5	0·0
Nil	3·0	2·0	1·5	1·0	1·5	0·5	2·5	2·5	2·5	1·0	0·5	0·0

DISCUSSION.

Comparison of results with those of previous years.

Long Ashton. The Majestic samples from this site in the two previous years had been very broken in flesh texture, but in 1947 they were rather too solid. Red King also had this tendency, but Kerr's Pink was again very broken on boiling. The extent of blackening on Plot 17a was very similar in the seasons 1944, 1945 and 1947 and was associated with K deficiency.

Blackening was most evident in the no-manure and NP plots and in Kerr's Pink it was only appreciable in the NP plots.

Centre II. (Swaffham). The 1947 results cannot be compared directly with those of previous years as the only fertiliser treatment in 1947 was the possible residual effect of the 1945 dressings. Furthermore Arran Consul was grown in 1947 as against Majestic in the previous tests. The general character of the samples was, however, again poor and blackening was severe. There was no clear-cut effect of the earlier treatments on the quality of the 1947 crop : in 1945 the effects had been definite although limited in extent.

Centre V. (Sutton Park). The general tendency at this site was, as in previous years, to give potatoes of poor texture and liable to show extensive blackening. The samples of Majestic grown in former years had shown this very clearly and this variety was similarly of poor quality in 1947. The other varieties, however, varied considerably in behaviour. Without lime, growth was again poor in all varieties and fertilisers had little effect on quality ; only Kerr's Pink showed a response to K, although Majestic had shown some effect before liming in 1946. After lime had been applied to the plots there was again an improvement in texture in most varieties but an increase in blackening as was also found in previous years. Fertiliser effects than became more apparent and K manuring improved colour very considerably in all varieties except Gladstone and Majestic. The amount of blackening in Majestic was much greater than in former seasons and the response to K was inconclusive, although previously the effect had been very definite.

Varieties and Sites.

In these trials Majestic was only grown at two sites (Long Ashton and Sutton Park) and Arran Consul at one site where Majestic had formerly been grown. Two other varieties were grown with Majestic at Long Ashton and five other varieties at Sutton Park. At Long Ashton the three varieties Majestic, Red King and Kerr's Pink were of fair quality, but Majestic, as in former years, showed the greatest tendency to blacken. Red King was the best in all-round quality, for Kerr's Pink, although the best in colour, was excessively broken and disintegrated on boiling. At Swaffham, Arran Consul resembled the Majestic samples previously obtained from this site and showed extensive blackening and a solid texture.

Of the six varieties at Sutton Park, Kerr's Pink and Dunbar Rover showed the least susceptibility to the local acidity conditions in so far as cooking quality was concerned. These varieties also showed the best level of growth as judged by visual observations during the season. Texture was fairly good and blackening could be decreased by K fertilisers. Of the two varieties, Dunbar Rover showed the greater tendency to blacken. Arran Banner and King Edward were poorer in quality but blackening was again responsive to K. Gladstone was similar in general quality to Arran Banner and King Edward but showed no improvement in texture after liming, although yield was increased and the plants showed much increased vigour ; Gladstone also showed little response to K and blackening was not consistently affected. Majestic was inferior to the other varieties at the site and blackened more severely than in previous years. It gave some improvement in quality on liming but blackening was little affected by fertiliser treatment.

A detailed account of the mineral nutrition status on the site and of the visual observations is given elsewhere in this Report (p. 97).

Manurial Treatments.

The results of the earlier trials have shown that the correction of mineral deficiencies has given an improvement in potato cooking quality, the amount of improvement depending on the severity of the conditions, the site and the variety. The present tests have again brought out the effect of K on blackening and, to a less degree, the effect of P on improving texture.

At Long Ashton, blackening was associated with conditions of severe K deficiency as shown by the foliage effects and tuber yields. The degree of blackening and the fertiliser response varied according to variety, but blackening could be eliminated in each case. At Sutton Park, the response to fertilisers was shown to be modified by the effect of variety to an even greater extent. Although blackening was always associated with K deficiency its severity and the improvement brought about by the fertiliser treatments were both dependent on the variety of potato.

The use of lime to correct the calcium deficiency and acidity conditions at Sutton Park invariably gave an increase in yield. The texture of the potatoes was improved at the same time but the extent of the improvement was again influenced by variety. The effect of P on texture was also seen at this site and deficiency of this element in some of the no-manure plots was associated with poor texture ; furthermore, in most varieties, the PK dressings had a more beneficial effect on texture than K dressings alone.

At Swaffham, the residual effects of the earlier fertiliser treatment were slight. Some symptoms of K deficiency were seen in the foliage of plants on the plots which had not received K in 1945, but there were no significant differences in vigour. In 1945 poor quality and blackening were found to be associated both with K deficiency and with other less specific site factors. In 1947, with no added manures, the site effects were again apparent.

CONCLUSIONS.

The results of the 1947 tests are in agreement with those of previous years in showing that potato quality is affected by the site, the variety and the nutritional status of the plant. Blackening after boiling has again been found associated with K deficiency, but the degree of blackening and the improvement brought about by fertiliser treatment have both varied according to the site and the potato variety. The varieties Red King and Kerr's Pink showed less liability to blacken than the varieties Dunbar Rover, Arran Banner, King Edward, Gladstone or Majestic. Of the latter varieties Majestic showed the greatest tendency to blacken. In general quality, the best varieties in these tests were Red King, Kerr's Pink, Dunbar Rover, Arran Banner and King Edward, but while Kerr's Pink showed the least liability to blacken, it suffered from excessive breakage on boiling and was thus inferior in general quality to Red King.

SUMMARY.

1. Further studies have been made of the factors affecting the cooking quality of potatoes, with particular attention to the incidence of blackening on boiling.

2. Samples were taken from three centres which had been included in earlier tests and which had shown, in varying degrees, deficiencies of N, P, K, Ca and Mg.

3. In previous trials, quality was found to be affected by the nutritional

status of the plant, but was modified by the effects of both site and variety. In the present tests few sites were studied, but the number of varieties was increased.

4. Eight varieties were tested, viz: Kerr's Pink, Red King, Dunbar Rover, Arran Banner, King Edward, Gladstone, Arran Consul and Majestic; six of these were grown on one site.

5. On two sites blackening was associated with K deficiency and the correction of this deficiency produced an improvement in the colour of the samples. On the better site the degree of blackening varied according to variety, but in all varieties it could be practically eliminated by fertiliser treatment. On the poorer site the varieties again blackened to varying extents, but in some varieties the response to fertilisers was insufficient to remove blackening completely.

6. The texture of the samples was adversely affected by the acidity conditions associated with Ca deficiency and also by P deficiency. The correction of these conditions gave an improvement in the texture and appearance of the samples, the amount of improvement depending on the variety of potato.

7. Blackening was least in Red King and Kerr's Pink, but when grown at one site Kerr's Pink showed too much breakage on boiling. On the other site Kerr's Pink showed the best general quality. Dunbar Rover, Arran Banner and King Edward were next in order of quality on this latter site but showed more blackening. Gladstone was rather inferior in quality and blackened more extensively but made good growth under unfavourable conditions. Majestic and Arran Consul both showed very severe blackening on two sites.

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